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International Journal of Cognitive Research in Science, Engineering and Education

(IJCRSEE)

EDITORIAL

International Journal of Cognitive Research in Science, Engineering and Education (IJCRSEE) is an open access international peer-reviewed, open-access journal, which provides a platform for highlighting and discussing various cognitive science issues dealing with the problems of cognition (and its evolution) within some specific subject field - philosophical, psychological, linguistic, mathematical, psychogenetic, pedagogical, ergonomic. Editorial Board strives to provide a possibility for the scientists of different fields to publish the results of their research, technical and theoretical studies. IJCRSEE is multidisciplinary in approach, and will publish a great range of papers: reports of qualitative case studies, quantitative experiments and surveys, mixed method studies, action researches, meta-analyses, discussions of conceptual and methodological issues, etc. IJCRSEE publisher is The Association for the Development of Science, Engineering and Education, Vranje, Serbia. Co-publishers are: University Business Academy, Faculty of Economics and Engineering Management in Novi Sad, Serbia and Don State Technical University, Rostov on Don, Russian Federation.

IJCRSEE particularly welcomes articles on the results of scientific research in various fields of cognitive science (psychology, artificial intelligence, linguistics, philosophy and neuroscience) catering for international and multidisciplinary audience. Readers include those in cognitive psychology, special education, education, adult education, educational psychology, school psychology, speech and language, and public policy.IJCRSEE has regular sections: Original Research, Review Articles, Studies and articles, Book Reviews, Case Studies, and is published three times a year. This journal provides an immediate open access to its contents, which makes research results available to the public based on the global exchange of knowledge. The journal also offers access to uncorrected and corrected proofs of articles before they are published.

The main aim of the Journal is to discuss global prospects and innovations concerning major issues of cognitive science, to publish new scientific results of cognitive science research, including the studies of cognitive processes, emotions, perception, memory, thinking, problem solving, planning, education and teaching, language and consciousness study, the results of studying man's cognitive development and the formation of basic cognitive skills in everyday life. The Journal seeks to stimulate the initiation of new research and ideas in cognitive science for the purpose of integration and interaction of international specialists in the development of cognitive science as interdisciplinary knowledge.

All articles are published in English and undergo a peer-review process.

The scope of IJCRSEE is focused on cognitive research both in topics covered as well as disciplinary perspective:

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IJCRSEE provides a platform for academics and scientists professionals to refer and discuss recent progress in the fields of their interests. Authors are encouraged to contribute articles which are not published or not under review in any other journal.

Each submitted manuscript is evaluated on the following basis: the originality of its contribution to the field of scholarly publishing, the soundness of its theory and methodology, the coherence of its analysis, its availability to readers (grammar and style). Normal turn-around time for the evaluation of manuscripts is one to two months from the date of receipt.

Submission of an original manuscript to the journal will be taken to mean that it represents original work not previously published, that is not being considered elsewhere for publication; that the author is willing to assign the copyright to the journal as per a contract that will be sent to the author just prior to the publication and, if accepted, it will be published in print and online and it will not be published elsewhere in the same form, for commercial purposes, in any language, without the consent of the publisher.

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Writing – Please write in good English (American or British usage is accepted, but not a mixture of these). For non-native English speakers, and perhaps even for some native English speakers, grammar, spelling, usage, and punctuation of the texts are very important for an effective presentation. Hence, manuscripts are expected to be written in a clear, cogent, and readily understandable by an international readership.

Manuscripts must be submitted online. Electronic submission reduces the editorial processing and reviewing time. As part of the submission process, authors are required to check off their submission compliance with all of the following items, and submissions may be returned to authors who do not adhere to the following guidelines:

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The text is single-spaced; uses a 12-point font; employs italics, rather than underlining (except with URL addresses); and all illustrations, figures, and tables are placed within the text at the appropriate

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The text adheres to the stylistic and bibliographic requirements outlined in the Author Guidelines.

If submitting to a peer-reviewed section of the journal, the instructions in Ensuring a Double Blind Review have been followed.

A manuscript goes through the peer review process. Authors submit manuscripts to Editorial office via the online system. The acknowledgement letter should be sent to the author to confirm the receipt of the manuscript. The Chief Editor first reviews manuscripts. Chief Editor is assisted by Section Editors (could also be Co- or Associated Editors). The Editor assigns a Section Editor to see the manuscript through the complete review process and return it with a recommendation or decision. The manuscript is checked to see if it meets the scope of the Journal and its formal requirements. If it is incorrect or unsuitable, the author should be informed and the manuscript filed (or returned if requested) – direct rejection. Manuscripts that are not suitable for publication in the Journal are rejected. A Rejection letter is sent to the author stating the reason for rejection. If the manuscript conforms to the aims and scope of the Journal, and formally abides by the Instructions to Authors it is sent out for review. Depending on the type of paper, it could be accepted immediately for publication (invited Editorial, Book review etc) by the Chief Editor.

Check that the manuscript has been written and styled in accordance with the Journal style; that it carries an abstract (if applicable), keywords, correct reference system etc. and check that the correct blinding system has been used. If anything is missing ask the author to complete it before the manuscript is sent out for review.

The manuscript is sent out for review. The reviewer reads and evaluates the manuscript and eventually sends a review report to the Chief Editor. The time for review can be set to 2-6 weeks depending on the discipline (more time is usually given to papers in the humanities and social sciences). Make sure to provide the reviewer with clear instructions for the work, e.g. outlined in the form of a Review report or a number of questions to be considered.

Based on the reviewers' comments the Chief Editor makes a decision to:

- Accept the manuscript without further revision
- Accept after revision
- Ask authors to resubmit
- Reject

An acceptance letter is sent to the author and the final manuscript is forwarded to production. Sometimes, the authors are requested to revise in accordance with reviewers' comments and submit the updated version or their manuscript to the Chief Editor. The time for review can be set to 2-6 weeks depending on the discipline and type of additional data, information or argument required. The authors are requested to make substantial revisions to their manuscripts and resubmit for a new evaluation. A rejection letter is sent to the author and the manuscript is archived. Reviewers might be informed about the decision.

After review a manuscript goes to the Copy Editor who will correct the manuscript concerning the correct referencing system, confirmation with the journal style and layout. When Copy Editor finishes his/her work they send manuscripts to the Layout editor.

Layout Editor is responsible for structuring the original manuscript, including figures and tables, into an article, activating necessary links and preparing the manuscript in the various formats, in our case PDF and HTML format. When Layout Editor finishes his/her job they send manuscripts to Proof Editor.

Proof Editor confirms that the manuscript has gone through all the stages and can be published.

This issue has 23 articles (20 Original researches and 3 Review articles). Our future plan is to increase the number of quality research papers from all fields of science, engineering and education. The editors seek to publish articles from a wide variety of academic disciplines and substantive fields; they are looking forward to substantial improvement of educational processes and outcomes.

Editor in Chief
Prof. Dr. Lazar Stošić, Senior Research Fellow

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Impact of Perceived Research-Based Teacher Education on the Perceived Research Competence of Pre-Service Teachers

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Abstract: This study examines the impact of perceived research-based teacher education on the development of pre-service teachers' perceived research competence. A new instrument was developed to measure perceived research-based teacher education at the programme level, capturing aspects such as participation in faculty-led research projects, opportunities for dissemination of results and involvement in the institutional research culture. The data were collected from 234 master's students enrolled in Slovenian teacher education programmes. Participants completed a questionnaire that assessed both perceived research-based teacher education and three dimensions of perceived research competence: perceived research knowledge, perceived research skills and research attitudes. The results showed that pre-service teachers perceive a moderate presence of perceived research-based teacher education in their study programmes and a moderate level of perceived research competence. Furthermore, regression analyses revealed a significant relationship between perceived research-based teacher education and all three components of perceived research competence, with the largest effect observed for perceived research skills. These findings show the potential of systematic, institution-wide support for research experiences in teacher education, including collaborative projects, faculty and student research efforts, and opportunities to apply and present research findings. By strengthening the elements of research-based teacher education, programmes can help pre-service teachers develop the knowledge, skills and attitudes necessary for evidence-based practice.

Keywords: *perceived research-based teacher education, pre-service teachers, perceived research competence, evidence-based practice, educational research.*

Introduction

The teaching profession is undergoing important changes, where researchers are increasingly emphasising the importance of a research-based teacher education where the aim is to educate pre-service teachers to be reflective, evidence-informed professionals capable of adapting to rapidly changing classroom tasks (Brew and Saunders, 2020; Matjašič and Vogrinc, 2025a; Munthe and Rogne, 2015). In countries known for high educational achievement (e.g., Finland), research-based teacher education is a key feature of teacher education and is often associated with success in student knowledge assessments. Finnish teacher education, for example, requires all pre-service teachers to have a master's degree that includes in-depth research practice. This means that pre-service teachers familiarise themselves with scientific research, write research-based texts and take special courses on research methodology. In addition, they carry out their own research projects for their bachelor's and master's theses, apply scientific methods and gain insights into data collection methods, systematic analytical thinking, interpretation and evaluation (Jakhelln et al., 2019). According to Krokfors et al. (2011), there are four main features of research-based teacher education: (1) the study programme is structured according to a systematic analysis of education; (2) teaching is based on research; (3) pre-service teachers engage in activities that foster argumentation, decision-making, and justification in investigating educational problems; and (4) pre-service teachers improve their research skills as part of their studies. The underlying idea is that

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pre-service teachers learn to view teaching as an evidence-based profession from the beginning of their education. In Slovenia, academics have similarly emphasised the role of the teacher as researcher. For example, Krek and Vogrinc (2007) discuss the concept of the "teacher-researcher of educational practice" and argue that teachers should acquire the ability to systematically investigate their own and others' educational practice during their education. By positioning pre-service teachers as producers and consumers of research, research-based teacher education aims to professionalise teaching in line with other research-based areas and improve the overall quality of education.

Within research-based teacher education, research competence is the main concept that enables pre-service teachers to critically engage with educational research, conduct their own investigations and apply research findings to improve their teaching practice (Agud and Ion, 2019; Matjašič and Vogrinc, 2025a). Research competence is usually conceptualised as comprising three interlinked dimensions: research knowledge, research skills and research attitudes (Matjašič and Vogrinc, 2024). Pre-service teachers who can understand research findings, conduct research (e.g., small-scale research projects) and make data-informed decisions are better equipped to improve their learning and be innovative in their future teaching. This perspective builds on the concept of "teacher as researcher" (Stenhouse, 1975), which positions practicing teachers as central agents in curriculum development through classroom inquiry and collaboration with academic researchers. Later scholars, such as Krek and Vogrinc (2007) and Saqipi and Vogrinc (2016, 2020), extended this concept to pre-service teachers, emphasising the idea that pre-service teachers should proactively investigate and reflect on their practice to promote continuous improvement. Aligning teacher education with this vision means that pre-service teachers are not just passive recipients of knowledge, but are actively involved in the creation and evaluation of knowledge, particularly through the investigation of their experiences in classroom practice. In turn, the development of research competence during teacher education is seen as crucial for educating pre-service teachers who can bridge the gap between theory and practice (Magnaye, 2022; Matjašič and Vogrinc, 2025a). As highlighted by Toom et al. (2010), educational reforms and professional development initiatives increasingly emphasise the integration of research processes into teacher education, highlighting that a research-based teacher education fosters the reflective, inquiry-oriented mindset necessary for continuous professional development. The ability to engage with research is now recognised as one of the most important competences for pre-service teachers and is influencing policy and curriculum design in teacher education around the world (Aspfors and Eklund, 2017; van Katwijk et al., 2019). With this in mind, investigating the impact of research-based teacher education on pre-service teachers' research competence is both timely and important to understand how such education shapes the next generation of teachers.

Theoretical Framework

Research-based teacher education

Several theoretical frameworks explain why and how integrating research into teacher education is important. One perspective cited by many authors (e.g., Rutten and Wolkenhauer, 2024; van Katwijk et al., 2021) is the concept of teacher "inquiry as stance", defined as a way of looking, acting, and having a habitual, continuous attitude (Cochran-Smith and Lytle, 2009). Engaging in systematic inquiry is not just an activity for pre-service teachers, but a professional stance that pre-service teachers carry into their careers, characterised by continuous questioning, reflection, and investigation into teaching and learning. Rather than treating research as an add-on, the inquiry stance concept embeds research-mindedness into teachers' professional identity (Cochran-Smith and Demers, 2010). When teachers take an inquiry stance, they act as reflective practitioners (Schön, 1983), pose questions or "wonderings", collecting data to gain insights into their wonderings, analysing the data along with reading relevant literature, making changes in practice based on new understandings developed during inquiry, and sharing findings with others (Dana and Yendol-Hoppey, 2014, p. 12). Teachers with an inquiry stance view their classrooms as spaces for ongoing learning as they formulate questions about their practice, collect and analyse data and use evidence to guide improvements. Cochran-Smith and Lytle (2009) argue that such a stance empowers teachers to be individuals of change in their own classrooms and schools, fostering a mindset of lifelong learning. This aligns with broader notions of teachers as reflective practitioners (Schön, 1983). Schön (1983) argues that the act of reflection in teaching is not simply a retrospective process that happens once

a lesson or task is completed, but an ongoing process that occurs in the middle of the action. By positioning inquiry at the heart of teaching, these perspectives provide a powerful rationale for research-based teacher education: if we want pre-service teachers to be inquiring professionals, teacher education must cultivate that disposition from the start.

The recognition that research-based teacher education contributes to better educational outcomes has also been emphasised by the European Commission and the Organisation for Economic Co-operation and Development (OECD), which advocate greater integration of research into teacher education. Both organisations emphasise the need for pre-service teachers to develop the skills and dispositions required to engage with research during their education (European Commission, 2015; OECD, 2023). Recent OECD analyses (OECD, 2023) particularly emphasise that pre-service teachers benefit from a systematic approach to research-based teaching, opportunities for critical questioning and regular practice in reflecting on and adapting their teaching strategies. Furthermore, the European Commission (2015) suggests that in order to achieve a creative and reflective teaching workforce, policies and actions should encourage pre-service teachers to utilise and engage with new research findings in their learning and practice.

The aim of research-based teacher education is pedagogically-thinking, reflective and inquiry-oriented teachers (Toom et al., 2010). This means that the purpose is not to educate researchers or even teacher-researchers per se. The objective is to acquire an inquiring attitude to teaching. Thus, pre-service teachers are able to observe, analyse and develop their work. Teachers' pedagogical thinking means the ability to conceptualise everyday phenomena, to look at them as part of a larger instructional process and to justify decisions and actions made during this process (Toom et al., 2010). In essence, a research-based teacher education aims to integrate the education of pre-service teachers with the processes of knowledge generation, fostering an inquiry as stance (i.e., a disposition to question and investigate classroom practice). Several conceptual models delineate forms of research integration in teaching. For example, Griffiths (2004) identified four modalities of linking research and teaching in higher education: research-led (curriculum driven by teacher-researchers' interests), research-oriented (emphasising learning inquiry skills and understanding research processes), research-based (curriculum organised around research activities rather than just content acquisition), and research-informed (drawing on existing research about teaching and learning). According to Štemberger (2020), all four modalities are valid, and they should all be present in research-based teacher education. In general, research-based teacher education means that pre-service teachers carry out research in their courses independently and with an open outcome, thus enabling them to internalise and practice research approaches and methods, including the skills of formulating precise questions and processing and monitoring the research process (Štemberger, 2020).

Concrete frameworks for implementing research-based teacher education have been proposed in policy and research. One prominent example is the British educational research association report (BERA and RSA, 2014), which outlined multiple dimensions of a research-based teacher education. According to this report, research can contribute to teacher education in at least four ways (1) informing the content of teacher education (ensuring curricula are built on up-to-date, research-based knowledge); (2) guiding the design and structure of programmes; (3) equipping pre-service teachers and educators to be discerning consumers of research; and (4) involving both teacher educators and pre-service teachers as active researchers, to investigate the impact of particular interventions or to explore the positive and negative effects of educational practice. These dimensions underscore that a research-based teacher education is not just about adding a research methods course or a thesis requirement, but cultivating an overall culture where research competence and research are interrelated throughout the coursework and field experiences. This holistic view is supported by Alvunger and Wahlström's (2018) study of Swedish teacher education, in which the authors argue that "education as a whole must be included in the concept of research-based education", meaning that every component of the programme (not just isolated research projects) should reflect scientific rigour and encourage critical examination. In summary, the theoretical foundation of research-based teacher education lies in the development of teachers who can think and act as research-based practitioners who connect theory and practice by using inquiry to continuously improve their teaching and their students' learning.

The implementation of research-based teacher education usually includes several important steps. First, research content is included across courses, for example, pre-service teachers learn how to read and interpret educational research, apply research findings to classroom challenges, and use data to inform decision-making. Second, pre-service teachers often carry out their own research (e.g., action

research projects) under the guidance of teacher educators who themselves exemplify scientific research. The aim of this guidance is not only the production of a thesis document, but to help pre-service teachers see themselves as researchers in their field. By engaging in research activities, pre-service teachers can develop a habit of questioning and investigating educational problems systematically, rather than relying on intuition alone (van Katwijk et al., 2023). Third, research-based teacher education implies that the curriculum and teacher education are research-based. In essence, research becomes both the content, and the means of teacher education where pre-service teachers learn about research, through research, and for the purpose of enhancing educational practice.

Research competence

The need for research-based teacher education goes hand in hand with an emphasis on the development of research competence. In the context of teacher education, research competence is the ability of pre-service teachers to understand and conduct research, critically evaluate findings and use research as a tool to improve their teaching practice (Matjašič and Vogrinc, 2024; Matjašič and Vogrinc, 2025a). This competence is not only about acquiring skills and knowledge related to research methods, but also about developing research-oriented teachers who are able to observe, analyse and develop their work. In other words, research-based teacher education should support the development of the knowledge, skills and attitudes that pre-service teachers need to become active, evidence-based practitioners. Moreover, for teachers to stay research-oriented, research must be trustworthy and practically useful for them. According to Westbroek et al. (2022) this means that teachers' new idea (comprising research problem and research questions) fit existing lesson goals, so it does not undermine what the class already has to achieve, that teachers have clear, step-by-step guidance (e.g., from other researchers) on how to apply the new idea in everyday lessons, and that putting it into practice adds a small amount of extra time or effort. According to Westbroek et al. (2022), the criteria of congruence, clear guidance and low cost translate the teacher as researcher concept into a daily micro-cycle in which teachers continually observe lessons, analyse emerging evidence and adjust their instruction, thereby embedding research activity in routine classroom decision-making.

Although much of the literature still relies on self-reports, we identified only two that explicitly compared perceived with actual (i.e., objectively assessed) research competence, and both found discrepancies. A study of Slovenian master's students (Matjašič and Vogrinc, 2025b) collected perceived and actual research competence at two time-points and showed that participants initially overestimated their actual research competence. This difference narrowed after the students took part in a research-based course but did not disappear entirely. Similar results were also observed in study by Böttcher-Oschmann et al. (2021), in which students initially overestimated their actual research competence, but the more they conducted research as part of their research-based projects their perceived research competence more closely matched their actual research competence. These studies show that if pre-service teachers overestimate their research competence, research-based preparation is even more crucial.

Recent studies have shown that research-based teacher education can improve students' perceived research competence. For example, Thiem et al. (2023) showed how participation in an entire research process led to significant improvements in various dimensions of perceived research competence. Their study found that students who actively participated in research-based learning reported higher self-assessments in terms of research review, methodological skills, reflection on research findings, communication and content knowledge. By using a quasi-experimental design with fixed-effects panel regression models, the authors were able to infer that these improvements were a direct result of the experience of the entire research process and not just a function of overall academic development. Furthermore, the study by Matjašič et al. (2023) showed that the integration of research-based teaching into teacher education is important because it increases perceived research competence, especially research attitudes, perceived research skills and perceived research knowledge, and thus can improve the quality of teacher education. These findings align with results from Böttcher-Oschmann et al. (2021), who found that involving pre-service teachers in research-learning projects develops their competencies for evidence-based practice. Specifically, structured and authentic research-learning environments improved students' abilities to systematically review literature, employ methodological strategies, and effectively communicate research outcomes. Practical implications from these studies suggest that teacher educa-

tion should include systematic and supported opportunities for students to engage directly in research processes to promote research competence and prepare pre-service teachers to confidently engage in evidence-based practice.

Despite the recognised importance of research-based teacher education and the acknowledged need to develop research competence, there are several important gaps in the literature. First, the measurement of research-based teacher education tends to focus on the extent to which research is used to inform teaching and how research is embedded in the course. However, there is still a lack of standardised instruments to measure research-based teacher education. Krokfors et al. (2011), for example, surveyed teacher educators on how they conceptualise and practice a research-based teacher education. While their work explores how research-based elements are integrated into the course (particularly in seminars and thesis-related assignments), it does not capture broader programme-level issues such as whether students have had the opportunity to interact with researchers, contribute to faculty-led investigations, or present their own research in a formal setting. A similar observation applies to the studies by Munthe and Rogne (2015) and Brew and Saunders (2020). Both studies highlight how differently teacher educators interpret and implement research-based initiatives in their courses and emphasise the diversity of rationales and teaching strategies used. Furthermore, Fiskum et al. (2025) point out that within research-based teacher education, there is still a lack of common understanding and consensus regarding what it means and how it should be organised. Therefore, we believe that for a better understanding of research-based teacher education we need information from all levels - from individual courses, from pre-service teachers, from teacher educators themselves and from the programme assessed not only by analysing course documents (Alvunger and Wahlström, 2018) or a curriculum analysis (Štemberger, 2020). Such a perspective can provide deeper insights into how research-based teacher education is systematically integrated and how effectively the programme supports a research-based culture. Furthermore, recent studies in teacher education (e.g., Afdal and Spernes, 2018; Alvunger and Wahlström, 2018) have shown the complexity of implementing research-based teacher education. Although these studies provide rich qualitative insights into the link between research and teaching (e.g., how teacher educators perceive the integration of teaching and research, what activities or strategies they use, and how they redesign their courses), they do not provide programme-level measures of research-based teacher education. Thus, there remains a need for instruments that can examine research-based teacher education beyond the level of a single course or research project and capture the multiple ways in which study programme can systematically encourage, support, and assess research engagement. Second, while several studies have investigated the development of pre-service teachers' perceived research competence through research-based course (e.g., Magnaye, 2022; Matjašič and Vogrinc, 2025a), we could not find any study that investigated the impact of perceived research-based teacher education at the programme level on pre-service teachers' perceived research competence. We argue that by analysing the impact at a programme level, it becomes possible to understand how perceived research-based teacher education practices contribute to the development of perceived research competence that extends beyond individual courses. Third, Štemberger (2020) examined teacher education curricula in Slovenia and found that more than half of the programmes do not explicitly include the acquisition of research competence as a stated goal. Study concludes that remains unclear to what extent the research elements are implemented in actual teaching practice. Accordingly, Štemberger (2020) emphasises the need for follow-up studies using alternative methods (e.g. questionnaires for pre-service teachers) to investigate how research is actually implemented and how pre-service teachers participate in research. Fourth, although it seems self-evident that embedding research tasks will automatically increase research competence, some studies report large increases in perceived research competence of students when they are engaged in research-based teaching (Thiem et al., 2023), whereas others find improvements only in specific domains (i.e., cognitive knowledge increased, but motivation decreased) after similar coursework (Gussen et al., 2023).

Research questions

Given these gaps, the present study aims to address two important issues. First, by developing a new instrument to measure perceived research-based teacher education, our study aims to provide a standardised instrument that can be used to evaluate and compare teacher education programmes and serve as a starting point for translation, adaptation and validation in other languages and contexts.

Second, by investigating the impact of perceived research-based teacher education on pre-service teachers' perceived research competence, the study not only tests whether the integration of research into the curriculum can increase pre-service teachers' perceived research competence but also how much does it increase.

Based on these gaps, the following research questions were answered:

RQ1: What is the level of perceived research-based teacher education and perceived research competence (i.e., perceived research knowledge, perceived research skills and attitudes) among students enrolled in master's programmes for pre-service teachers?

RQ2: What impact does the perceived research-based teacher education have on the perceived research competence (i.e., perceived research knowledge, perceived research skills and attitudes) of pre-service teachers?

Materials and Methods

Participants

The sample consisted of 234 master's students enrolled in teacher education at several Slovenian higher education institutions in the academic year 2023/2024 (Table 1). To check whether our sample was large enough after the data were collected (in order to answer RQ2), we ran a post hoc power analysis in R (package pwr). The procedure converts each observed coefficient of determination (R^2) into Cohen's f^2 and, using the non-central F distribution, estimates the probability of detecting an effect of that size at $\alpha = .05$. With N = 234 we had 99% power to detect the overall multivariate effect ($R^2 = .169$, $f^2 = 0.203$) and 88 % power for the smallest single-outcome effect ($R^2 = .098$). Both values exceed the conventional .80 benchmark, indicating that the study was adequately powered.

According to Slovenian regulations, primary and secondary school teachers must hold a master's degree, with several routes to obtaining a teaching qualification available. These include concurrent degree programmes offered primarily by pedagogical and multidisciplinary faculties (see Table 1), as well as consecutive degree programmes such as Pedagogical-Andragogical Education (PAE), which are designed for candidates with non-pedagogical degrees. Teachers (qualified for grades 1-5) study exclusively at faculties of education, while subject teachers (qualified for grades 6-9 and secondary education) study mainly at multidisciplinary faculties, where they acquire subject-specific knowledge as well as pedagogical skills and practical experience through school placements.

Table 1. *Participants*

University	Institution	N
University of Ljubljana	Faculty of Education	107
	Faculty of Arts	84
	Faculty of Chemistry and Chemical Technology	5
	Academy of Music	4
	Faculty of Theology	4
	Biotechnical Faculty	3
University of Maribor	Faculty of Education	13
University of Primorska	Faculty of Education	14

Instrument

Based on the literature review (Afdal and Spernes, 2018; Alvunger and Wahlström, 2018; Byman et al., 2009; Munthe and Rogne, 2015; Visser-Wijnveen et al., 2016), we developed 14 items, measured on a five-point Likert scale (1 - strongly disagree to 5 - strongly agree), measuring perceived research-based teacher education. To ensure content validity and clarity, the items were reviewed by a group of teacher education and curriculum development experts. Feedback from these experts was used to revise and refine the wording and content of the items. The revised instrument was then pilot tested with a sample of pre-service teachers. Minor adjustments were made based on the pilot data (i.e., one item was deleted, leaving the final set of 13 items).

To measure the perceived research competence, the questionnaire developed by Matjašič and

Vogrinc (2025a) was used. This questionnaire measures three key dimensions of perceived research competence: perceived research knowledge (15 items), perceived research skills (15 items) and research attitudes (15 items). Each dimension was measured on five-point Likert scale (1 - strongly disagree to 5 - strongly agree).

The questionnaire measuring both concepts was administered as a web-based survey. Students were informed of the aims of the study and assured that participation was entirely voluntary, with the right to withdraw at any time. They were also assured of complete anonymity and confidentiality. The data were securely stored, anonymised and analysed only in aggregate form to prevent identification of individual participants.

Analysis

All analyses were performed in R (R Core Team, 2022). To determine whether the factor structure of the perceived research competence questionnaire holds up, a confirmatory factor analysis (CFA) was conducted. The same was done for the items measuring perceived research-based teacher education. The confirmatory factor analyses were conducted using the lavaan package with the diagonally weighted least squares (DWLS) estimator for ordinal data. In addition, the item reliability analyses McDonald's omega (ω) and Cronbach's alpha (α) were calculated using the psych package. It should be noted that in addition to α, we have also calculated the ω because it provides a more robust estimate of internal consistency.

The CFA for the items measuring perceived research-based teacher education showed acceptable fit indices (CFI = .977, TLI = .972, RMSEA = .084, and SRMR = .073). These values fulfil the generally accepted thresholds for an acceptable model (Kline, 2016). In addition, all standardised factor loadings were significant ($p < .001$) and all were greater than .40 (Appendix A, Table A.1). Similar findings were observed for the items measuring perceived research competence (CFI = .952, TLI = .949, RMSEA = .066 and SRMR = .092) after excluding some standardised factor loadings that were less than .4 (see Appendix B, Tables B.1–B.3).

Once the factor structure and reliability of the scales had been confirmed, we first calculated the median and interquartile range (IQR) for the items measuring perceived research-based teacher education, due to violation of the assumption of normality as indicated by the Shapiro–Wilk test ($p < .05$ for all items). Because item-level descriptive statistics for perceived research competence have already been reported elsewhere (Matjašič and Vogrinc, 2025a), we did not replicate them here. Instead, we computed composite scores for each dimension of perceived research competence (perceived research knowledge, perceived research skills and attitudes) and perceived research-based teacher education by averaging the respective items. This allowed us to calculate descriptive statistics and assess the level of perceived research competence among students and also assess the impact of perceived research-based teacher education on pre-service teachers' perceived research competence using a multivariate multiple regression. We chose multivariate multiple regression because it accounts for the intercorrelations between the three dimensions of perceived research competence (knowledge-skills: $r = .73$, knowledge-attitude: $r = .41$, skills-attitude: $r = .39$), thus controlling for shared variance and reducing the risk of Type I error. As a Shapiro–Wilk test indicated deviations from normality for the composite perceived research knowledge ($W = 0.985$, $p = .013$) and the composite perceived research-based teacher education ($W = 0.987$, $p = .041$), we also used the Pillai's trace as a multivariate test statistic because it is robust to violations of normality (Olive et al., 2015). Univariate linear regressions were then performed to interpret the effects on each dimension, with bootstrapped confidence intervals (5,000 replicate samples) calculated for non-normally distributed outcomes. Standardised beta coefficients (β), 95% confidence intervals and effect sizes (η^2 and R^2) are provided to quantify the magnitude and practical significance of the relationships.

Results

We begin by presenting the descriptive statistics for the items measuring perceived research-based teacher education (Table 2).

Table 2. *Descriptive statistics for items measuring perceived research-based teacher education (n = 223), sorted from largest to smallest by median*

Item	Median	IQR
During my studies, I became acquainted with research conducted in my field of study.	4.00	2
During my studies, I had the opportunity to present the findings of my research work to my classmates.	4.00	2
During my studies, I had the opportunity to learn about the research work of my teachers and assistants.	4.00	1
The theory covered during our studies was supported by examples of specific research.	4.00	1
The faculty encourages international cooperation and the exchange of researchers from other countries.	4.00	1
During my studies, I had the opportunity to engage in discussions with researchers in the field of education.	3.00	2
During my studies, I had the opportunity to participate in student projects.	3.00	1
During my studies, I had the opportunity to write or contribute to writing a scientific or professional article.	3.00	2
During my studies, I had the opportunity to attend workshops, conferences, or seminars that emphasised the importance of research in the field of education.	3.00	2
During my studies, I conducted research independently or in collaboration with peers.	3.00	2
Teachers and assistants encouraged me to engage in research during my studies.	3.00	2
Scientific research work was an integral part of the study (e.g., familiarisation with research approaches, methods, and techniques characteristic of scientific research).	3.00	1
I am familiar with the research goals of the faculty.	2.00	1

From Table 2 we can observe that several items received relatively high median ratings (4.0), indicating that most students felt positively about certain aspects of perceived research-based teacher education. For example, many students reported being acquainted with research in their field of study and being taught theory supported by specific research examples. Students also indicated that they had the opportunity to present their research findings to classmates and learn about their teachers' and assistants' own research. Additionally, students perceived encouragement of international collaboration at the faculty level. On the other hand, the majority of items received median rating of 3.0 (items, such as participating in student projects, engaging in discussions with researchers, conducting research with peers, and writing or contributing to a scientific article) which suggests that while these experiences do occur, they may not be uniformly available to all students, given the relatively wide IQR values (1-2). Finally, the lowest rated item (median = 2) was students' familiarity with the faculty's research goals.

Next the descriptive statistics for the composite variables measuring perceived research-based teacher education and perceived research competence are presented (Table 3).

Table 3. *Descriptive statistics for composite variables*

Composite variable	N	Mean	Standard Deviation	Median	IQR	Shapiro–Wilk p
Research-based teacher education	223	3.26	0.65	3.23	0.79	.041
Knowledge	234	3.31	0.58	3.27	0.77	.013
Skills	230	3.50	0.58	3.52	0.67	.274
Attitudes	229	3.41	0.62	3.42	0.83	.227

Note: All composite variables represent perceived constructs

From Table 3, we can see neutral to moderate agreement between participants across the dimensions (median ≥ 3.23). The composite variable skills has a mean value of 3.50, indicating that on average, participants rated themselves as having a moderate level of research skills. Self-assessed understanding of research knowledge (median = 3.27) and attitudes (mean = 3.41) were also positive, but closer to neutral. On the other hand, the composite variable research-based teacher education had the lowest value (median = 3.23), which, although above neutral, suggests that participants feel that research-based practice could be emphasised more in curricula.

Finally a multivariate regression analysis was conducted to examine the extent to which perceived research-based teacher education impacts students' perceived research competence. The results are presented in Table 4.

Table 4. *Multivariate and univariate regression results predicting perceived research competence*

Outcome	β	SE	95% CI	p	R^2	V*
Knowledge	0.300	0.056	[0.165, 0.410]	< .001	.114	
Skills	0.304	0.053	[0.200, 0.408]	< .001	.127	.169
Attitudes	0.293	0.060	[0.175, 0.411]	< .001	.098	

Note: Predictor = perceived research-based teacher education, β = standardised coefficient; SE = standard error; CI = 95 % bias-corrected bootstrap confidence interval, V = Pillai's trace multivariate test (V = .169, F(3, 219) = 14.86, p < .001, η^2 = .17).

A multivariate regression analysis using the Pillai's trace revealed (Table 4) that perceived research-based teacher education significantly predicted pre-service teachers' perceived research competence (V = .169, p < .001). The results show that 16.9% of the variance in the multivariate outcome set (perceived research knowledge, perceived research skills, and attitudes) of perceived research competence is explained by perceived research-based teacher education. In addition, univariate linear regressions showed positive impact of perceived research-based teacher education on perceived knowledge (β = 0.300, p < .001), perceived skills (β = 0.304, p < .001), and attitudes (β = 0.293, p < .001), with the predictor explaining 9.8% to 12.7% of the variance in the results. We can also see that the standardised regression coefficient (β) is highest for the dependent variable skills (β = 0.304), followed by knowledge (β = 0.300) and attitude (β = 0.293). This indicates that perceived research-based teacher education has the strongest effect on the pre-service teachers' perceived research skills, followed by their perceived research knowledge and attitudes.

Discussion

This study investigated the relationship between perceived research-based teacher education and the perceived research competence of pre-service teachers. By developing an instrument to measure perceived research-based teacher education at programme level and analysing data from Slovenia, the results provide insights into the ways in which the integration of research into teacher education impacts the development of perceived research knowledge, perceived research skills and attitudes. Below we discuss the main findings, their implications, limitations and directions for future research.

First, by developing an instrument to measure perceived research-based teacher education at the programme level, we have addressed a gap in the existing literature (Afdal and Spernes, 2018; Ciraso-Calí et al., 2022; Fiskum et al., 2025; Munthe and Rogne, 2015), in which studies often focus on specific courses or master's theses and neglect broader programme factors, such as opportunities for students to engage in faculty-led research (e.g., "Teachers and assistants encouraged me to engage in research"), participate in collaborative projects, disseminate results (e.g., "present findings to classmates" or "write scientific articles"), and interact with the institutional research culture (e.g., "learn about faculty research goals« or "attend conferences"). By capturing these factors, our instrument provides a tool for measuring and evaluating curricula. For example, institutions that score poorly on "opportunities to engage in discussions with researchers in the field of education" or "opportunities to participate in student projects" could prioritise research symposia for students to foster a culture of inquiry and collegial learning, which is particularly important given the OECD (2023) recommendations for structured research integration in teacher education to improve pedagogical adaptability. Moreover, results from our study highlight that although research-based teacher education is integrated into the programme, the extent of student engagement differs widely. Some elements like connecting theory to current research are perceived to be well-established, whereas opportunities for deeper involvement in ongoing faculty research or clarity about broader research goals appear less consistent. This discrepancy may stem from variations in departmental resources, differences in faculty workloads, or uneven visibility of research initiatives.

Second, the moderate level of perceived research competence and perceived research-based teacher education observed in our study is additionally supported by the analysis of Štemberger (2020), who found that more than half of Slovenian teacher education programmes do not have explicit curricular goals related to research competence and that Slovenian institutions seem to prioritise research in isolated components (e.g., theses) rather than fostering a research-based culture of inquiry. The findings of the current study therefore highlight the need for systematic alignment between institutional policy, programme design and pedagogical practice. For Slovenian institutions, this could mean adopting the

BERA and RSA (2014) multidimensional model, which emphasises research-based curriculum design, modelling of scientific research by pre-service teachers and active participation of pre-service teachers in knowledge production. For example, pre-service teachers would be required to analyse peer-reviewed studies and design a small research project to test a strategy in the classroom, or teacher educators could present their research and involve pre-service teachers in data collection/analysis (e.g., coding interview transcripts). In this way, pre-service teachers would view research as a collaborative, iterative process rather than a solitary final project. Agud and Ion (2019) pointed out similar concerns at the Faculty of Education of the Universitat Autònoma de Barcelona and emphasised the need to redesign teacher education, because the traditional approach to educational research does not benefit teachers much. In their opinion, teacher education should focus on the effective implementation of a research-based approach to ensure a closer relationship between classroom reality and pedagogical theories and practices and to prepare pre-service teachers to integrate research into their future careers. Furthermore, Wæge and Haugaløkken (2013) have found that research on teacher education in many countries has shown that students view theory and practice in teacher education as incompatible or as part of different worlds. This can potentially have a negative impact on the pre-service teachers' opportunities for professional development, as such development should be based on the ability to view one's own teaching practice from a critical, theory- and research-based perspective.

Third, the findings of our study contribute to the growing body of literature that emphasises the role of research-based teacher education in promoting pre-service teachers' perceived research competence. The results suggest a significant positive relationship between perceived research-based teacher education and pre-service teachers' perceived research-related knowledge, skills, and attitudes. Specifically, perceived research-based teacher education explained 16.9% of the variance in perceived research knowledge, skills, and attitudes with the strongest effect observed for perceived research skills. These results are in line with the recent study by Bayrak Özmutlu (2022), which has shown that sustained research projects not only deepen pre-service teachers understanding of evidence-based practice, but also strengthen self-discipline, confidence and communication skills, outcomes that the author directly links to improved research competence. Furthermore, our results suggest that perceived research-based teacher education improves pre-service teachers' confidence in their ability to engage in research activities and that research activities and engagement during teacher education may be particularly effective in building the actual research skills required to conduct research. These findings support the notion that the model of the teacher as researcher (Stenhouse, 1975) can be effectively operationalised at a programme level, which is consistent with Cochran-Smith and Lytle's (2009) conceptualisation of "inquiry as stance" and results from study by Matjašič et al. (2023) who found that perceived research-based curricula significantly enhances pre-service teachers' self-assessed research knowledge, skills and attitudes, which is consistent with our findings. In addition, Thiem et al. (2023) found that conducting an entire research process improved students' self-assessed skills in terms of research review, methodology, reflection on research findings, communication, and content knowledge. Taken together, they concluded that the implementation of research-based learning pays off. The evidence from our study suggests that embedding research experiences throughout the study programme can enhance perceived pre-service teachers' research competence. However, further research is needed to deepen our knowledge of the effect of research-based teacher education on research competence.

Conclusions

Our study provides evidence that perceived research-based teacher education significantly increases pre-service teachers' perceived research competence, which extends to perceived research knowledge, perceived research skills and attitudes. Two practical implications can be derived from our findings. First, teacher education should consider adopting a systematic, institution-wide approach to research-based teacher education. This can be achieved by aligning institutional policies, curriculum design and educational practices to promote a sustainable research culture. For example, curricula could be enhanced by including activities that encourage active engagement with research, such as collaborative research projects (e.g., pre-service teachers have opportunities to participate in faculty-led research and collaborative projects which can help bridge theory and practice), research dissemination platforms (e.g., creating forums or symposia where pre-service teachers can present and discuss their research findings

may further cultivate an inquiry-oriented mindset) and integration of research in courses (embedding research elements in courses, rather than confining research experiences to specific modules or thesis work, can ensure that all pre-service teachers develop essential research skills and a critical, reflective stance toward their teaching practice). Second, the moderate levels of perceived research competence observed in our study suggest that current teacher education may benefit from revisiting and enhancing their research components. For example, teacher educators could be encouraged to model research practices in their teaching, thereby demonstrating the practical application of research in everyday classroom contexts. Institutions might also consider periodic curriculum reviews to ensure that research-based teacher education is not only present but effectively integrated and reflective of best practices as recommended by international standards. In doing so we can take the study by Wæge and Haugaløkken (2013) as an example. Their research demonstrated that a continuous interaction between theory and practice had a positive impact on the students' understanding of theory. The seminars (combining education science, subject didactics, and reflective discussions on classroom practice), arranged on a weekly basis throughout the semester, helped students to see connecting lines between theory and practice. These sessions enabled them to realise that theoretical knowledge offers practical strategies and insights that can be directly applied in the classroom.

Finally, it is important to acknowledge that our study has limitations. First, the use of self-reported, perceived measures of research-based teacher education and research competence introduces potential biases, such as social desirability or overestimation of ability. Although perceptions are critical to understanding pre-service teachers' confidence and preparedness, they may not fully align with objective abilities. Future studies should compare self-reports with performance-based assessments (e.g., ratings of research outcomes or knowledge tests) to validate these findings. Second, although the questionnaire has been tested for the Slovenian context, it has not yet been tested in other linguistic or cultural settings. For example, differences in institutional research culture or curriculum structures (e.g., the emphasis on action research in the Nordic models compared to other regions) could have an impact on how research-based teaching is perceived. Future research should validate and adapt the instrument in different linguistic and cultural contexts to confirm its cross-cultural applicability. Finally, longitudinal studies could clarify how sustained experiences with research-based teacher education impact pre-service teachers' perceived research skills, research knowledge, and attitudes during their education and in their professional careers.

Conflict of interests

The authors declare no conflict of interest.

Data Availability Statement

The derived data and the R code supporting the results of this study are available on request from the corresponding author. The data have been anonymised, but are not publicly available due to privacy issues.

Participant Consent Statement

All participants involved in this study consciously and voluntarily participated in the research.

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Ethics Approval Statement

The study was conducted in accordance with the Declaration of Helsinki and was reviewed and approved by the Ethics Commission of the Faculty of Education of the University of Ljubljana. Approval code 14/2023, on 29 August 2023.

Author Contributions

Conceptualization, M.M., and J.V.; methodology, M.M., and J.V.; software, M.M.; formal analysis, M.M..; writing—original draft preparation, M.M.; writing—review and editing, M.M., and J.V; validation, M.M., and J.V. All authors have read and agreed to the published version of the manuscript.

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Appendix A

Table A.1. *Descriptive statistics, standardised factor loadings, McDonald's ω and Cronbach's α for items measuring perceived research-based teacher education*

Item	Standardised factor loading	ω (α)
During my studies, I became acquainted with research conducted in my field of study.	0.631	0.94 (0.86)
During my studies, I had the opportunity to present the findings of my research work to my classmates.	0.720	
During my studies, I had the opportunity to learn about the research work of my teachers and assistants.	0.705	
The theory covered during our studies was supported by examples of specific research.	0.626	
The faculty encourages international cooperation and the exchange of researchers from other countries.	0.585	
During my studies, I had the opportunity to engage in discussions with researchers in the field of education.	0.498	
During my studies, I had the opportunity to participate in student projects.	0.671	
During my studies, I had the opportunity to write or contribute to writing a scientific or professional article.	0.555	
During my studies, I had the opportunity to attend workshops, conferences, or seminars that emphasised the importance of research in the field of education.	0.603	
During my studies, I conducted research independently or in collaboration with peers.	0.562	
Teachers and assistants encouraged me to engage in research during my studies.	0.762	
Scientific research work was an integral part of the study (e.g., familiarisation with research approaches, methods, and techniques characteristic of scientific research).	0.661	
I am familiar with the research goals of the faculty.	0.474	

Appendix B

Table B.1. *Standardised factor loadings, McDonald's ω and Cronbach's α, for the dimension perceived research knowledge*

Item	Standardised factor loading	ω (α)
I know how to theoretically substantiate the research problem of my study.	0.650	0.95 (0.88)
I know how to formulate research objectives.	0.617	
I know how to formulate research questions.	0.555	
I know how to formulate hypotheses.	0.466	
I know how to choose the most appropriate research methodology for my work.	0.579	
I am familiar with different sampling methods or selection of individuals suitable for my research.	0.534	
I am familiar with the characteristics of different data collection instruments (e.g., questionnaire, knowledge test, interview question list).	0.587	
I am familiar with different methods of verifying the quality of data collection instruments (e.g., validity and reliability of the instrument).	0.542	
I am familiar with the fundamental ethical principles of educational research.	0.542	
I am familiar with the characteristics of quantitative research approaches.	0.581	
I am familiar with the characteristics of qualitative research approaches.	0.570	
I am familiar with the characteristics of quantitative data analysis.	0.700	
I am familiar with the characteristics of qualitative data analysis.	0.696	

Table B.2. *Standardised factor loadings, ω and α, for the dimension perceived research skills*

Item	Standardised factor loading	ω (α)
I know how to find the literature necessary for the theoretical background of my research	0.593	0.95 (0.91)
I know how to cite the literature I have read.	0.446	
I know how to summarise the essence of the literature I have read.	0.580	
I know how to design a research plan.	0.758	
I know how to explain the purpose of my research.	0.694	
I know how to create various instruments for data collection (e.g., questionnaire, knowledge test, interview question list).	0.650	
I know how to check the quality of the designed data collection instrument (their validity and reliability).	0.685	
I know how to use software for statistical data analysis (e.g., SPSS).	0.431	
I know how to write a report on an empirical research study.	0.679	
I know how to write a summary of an empirical research report (e.g., for a seminar paper).	0.731	
I know how to describe the data collection process.	0.683	
I know how to formulate conclusions of the research based on the collected data.	0.747	
I know how to write a statistical interpretation of the statistical procedures used.	0.626	
I know how to present the results and findings of my research to a broader audience (e.g., to my classmates, at a conference).	0.643	
I know how to develop a plan (an action plan) for implementing changes in educational practice based on the findings of empirical research.	0.477	

Table B.3. *Standardised factor loadings, McDonald's ω and Cronbach's α, for the dimension research attitude*

Item	Standardised factor loading	ω (α)
I enjoy reading research reports.	0.676	0.93 (0.87)
Knowledge of research in the field of education helps me succeed in my studies.	0.706	
Understanding research in the field of education helps me grasp the theoretical concepts discussed in various courses.	0.708	
I am interested in research in the field of education.	0.582	
It is important to me that my teachers and assistants conduct research.	0.627	
I find it important for a teacher to use examples from their own research in lectures.	0.549	
For effective teaching at university, it is important that teachers and assistants engage in research.	0.601	
Teachers' research in schools helps solve everyday practice problems.	0.555	
When I work in a school, I will engage in research activities.	0.591	
Conducting research is a good way to improve a teacher's teaching.	0.557	
Conducting research is a good way to enhance the prestige of the teaching profession.	0.631	
I feel part of the faculty's research community.	0.406	

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PhD Students' Perceptions and Strategies For Managing Stress During Their PhD Studies

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Abstract: The combined effects of academic demands, the need for effective time management, balancing work and personal commitments, and financial challenges lead to a significant degree of stress among PhD students. Understanding how stress is perceived and managed is crucial to understanding the challenges faced by PhD students during their most intense period of academic study. The study aims to examine how doctoral students display stress during their studies. A specially designed Questionnaire on how doctoral students perceive and manage stress during their studies was created for this study. It had seven items, and respondents were asked to rate their level of agreement with each one on a five-point Likert-type scale. A sample of 438 doctoral students from the Republic of Serbia with varying demographic, professional, and academic characteristics was used in the study. ANOVA and correlation tests, among other statistical analyses, revealed a high degree of stress related to difficulties balancing personal and academic commitments, particularly for doctoral students who are self-funded and have jobs. Gender differences show that female PhD students experience higher levels of stress, older PhD students struggle to find time for relaxation, and employed respondents report higher levels of stress than their counterparts without jobs. Scientific disciplines also differ, so that PhD students in the humanities report high levels of pressure. In contrast, those in the natural and technical sciences are less stressed by the competitive aspect of their study. The results emphasize the necessity of specialized institutional support services, such as financial aid, mentorship, and adaptable stress management programs, in order to reduce stress and enhance PhD students' academic experiences.

Keywords: *stress, stressogenic aspects, doctoral studies, time management, academic institutional support.*

Introduction

Doctoral studies are the most advanced form of academic education that an individual can pursue, offering the opportunity to acquire the specialized knowledge and skills required to address complex issues in various scientific and artistic disciplines. Despite the wealth of prospects for professional growth that doctoral studies offer, they are frequently accompanied by several difficulties that can have a detrimental impact on doctoral students' academic performance and mental health. PhD students frequently experience higher levels of stress during their studies due to issues including having too many responsibilities, time constraints, financial instability, a competitive environment, and demanding academic requirements. Furthermore, certain stressors, like the academic environment's competitive culture and the varying expectations in scientific disciplines, can impede doctoral students' progress and general productivity (Pyhältö et al., 2009; Levecque et al., 2017; Karaman et al., 2019; Kordić, 2023).

According to the majority of authors, stress is a person's psychophysiological response to an imbalance between their personal resources and the needs of their environment, whereby they believe that the demands of the situation are greater than their capacity (Lazarus and Folkman, 1984). In an academic setting, stress in doctoral students is frequently caused by the belief that the demands of their studies are

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too much for them, which can result in emotions of dissatisfaction and personal insecurity (Bedewy and Gabriel, 2015; Maluckov, 2018). According to the research findings, the most frequent causes of stress for doctoral students are complicated tasks like writing a doctoral thesis, assessing one's accomplishments, balancing personal and academic commitments, and expectations surrounding the publication of scientific papers (Stubb et al., 2011, 2012; Schmidt and Hansson, 2018).

The authors of the relevant articles often examine the causes of stress from two fundamental perspectives: institutional and individual. PhD students report feeling more stressed on an individual basis due to issues like time management, financial strains, and balancing personal and academic obligations (Jairam and Kahl, 2012; Alkhawaldeh et al., 2023; Milovanović et al., 2023). However, during their studies, PhD students experience more anxiety and insecurity due to institutional factors like regular performance reviews, a competitive environment, and a lack of mentorship support (Schmidt and Hansson, 2018; Sverdlik et al., 2018).

Furthermore, PhD students' perceptions of stress are significantly influenced by their professional and demographic characteristics. According to earlier studies, female PhD students are more likely than their male counterparts to experience higher levels of stress, which may be related to taking on more social tasks and obligations (Cotton et al., 2017; Schmidt and Hansson, 2018). While unemployed PhD students report lower levels of stress than working ones, who have to handle professional and academic obligations, older PhD students are more likely to struggle to find time for relaxation (Sverdlik et al., 2018; Barry et al., 2018; Husić and Dautbegović, 2023). An individual's experience of stress during the most advanced period of academic study is significantly influenced by their financial status. While self-funded students often feel more strain due to the high cost of their studies, PhD students who receive budgetary support report feeling less stressed (Lovitts, 2001; Cotton et al., 2017). Additionally, the nature of study programs can affect stress levels. For example, students in the natural and technical sciences frequently have to deal with the demands of laboratory research and results publication, whereas students in the social sciences and humanities report higher levels of stress because of the difficulties of conducting field research (Stubb et al., 2012; Schmidt and Hansson, 2018; Miltojević et al., 2022).

Anxiety, depression, and burnout are among the detrimental effects of high stress levels on PhD students' mental health (Pascoe et al., 2020). Additionally, stress might lower a person's academic performance and satisfaction with studies (Bedewy and Gabriel, 2015). A combination of individual tactics, including time management techniques, utilizing social support, building mental resilience, and implementing institutional measures, is necessary for effective stress management (Walker et al., 2008; Pyhältö et al., 2012; Turkal and Richardson, 2018; Trigueros et al., 2020). Flexible academic requirements, mental health promotion programs, and consistent mentorship assistance are some ways that higher education institutions can help reduce stress (McAlpine and McKinnon, 2013; Lonka and Ketonen, 2019; Simić and Vranješević, 2022). The key to lowering stress and improving doctoral students' academic performance lies in effective time management, as well as intellectual and social support (Pyhältö et al., 2012; Mijatović and Strižak, 2023; Knežević and Polak, 2024).

Research analyzing the differences in stress levels based on academic, occupational, and demographic variables is uncommon, despite the large number of studies on the prevalence of stress among PhD students. Although time management techniques, institutional support, and mentoring have been recognized as important stress-reduction variables, little is known about how these elements impact various PhD student populations. In order to identify the variations in the levels of particular aspects of stress among various groups of doctoral students and the relationship between the level of certain aspects of stress and age and length of work experience, the research was conducted in the context of examining the expression of key stress-inducing factors, adhering to the previously mentioned framework. Additionally, the study analyzed the overall stress level and found correlations and variations among the variables indicated.

Materials and Methods

The study aims to investigate how doctoral students manage stress while pursuing their doctoral degrees. The goal was operationalized using the following tasks:

1. To investigate how different stress-managing factors manifest during doctoral studies, such as the capacity to control stress, the ability to find positive ways to lessen overload, the ability to cope with a competitive environment, the effectiveness of time management, the frequency of achievement

evaluations, the ability to balance academic and personal commitments, the ability to secure quality free time for relaxation, and the overall level of stress;

2. Ascertain the differences in the level of success of using the named stress management techniques in light of the various academic, professional, and demographic traits of PhD students;
3. Ascertain the relationship between doctorate students' age and duration of work experience and the ability to manage stress;
4. Identify the differences in the overall stress management associated with doctoral studies, taking into account the various academic, professional, and demographic traits of doctoral students;
5. To identify the correlation between doctoral students' age and duration of job experience and the overall degree of stress management behaviours associated with their studies.

The primary research hypothesis is that PhD students experience a significant amount of stress while pursuing their degrees. Additionally, the following auxiliary hypotheses were proposed:

H_1: The ability to manage stress, finding constructive ways to reduce overload, coping with a competitive environment, time management efficiency, the frequency of achievement evaluations, balancing academic obligations with personal life, and securing quality free time for relaxation are all significant stress-managing aspects of doctoral studies. These factors are reflected in the overall stress level of doctoral students, with those who manage their time more effectively reporting lower levels of stress.

H_2: Certain aspects of doctoral students' stress levels vary statistically significantly based on their academic, professional, and demographic characteristics; female doctoral students, unemployed students, and students who finance themselves all exhibit higher levels of stress, whereas no statistically significant difference was found when it came to belonging to a particular scientific or artistic field;

H_3: There is a statistically significant correlation between doctoral students' age and length of job experience and the degree of specific stressors, with older doctoral students and those with more work experience reporting greater levels of stress;

H_4: While there are no differences observed between doctoral students in different scientific or artistic fields, there are statistically significant differences in the overall level of stress among doctoral students when taking into account various demographic, professional, and academic characteristics; male doctoral students who are employed and self-financed exhibit a higher level of stress;

H_5: There is a statistically significant correlation between doctoral students' total stress level and their age and length of work experience; older doctoral students report higher levels of stress overall, but there is no significant correlation between the two variables.

The study included 438 doctoral students, 62.6% of whom were female, from various universities in the Republic of Serbia who are currently enrolled in doctoral programs. The average age of the respondents is M = 31.63 (SD = 4.81), with a range of 21 to 45 years. With an average tenure of M = 6.71 years (SD = 4.42), the majority of respondents (92.2%) are employed. When it comes to the scientific and artistic fields, the highest percentage of participants (40.9%) came from the social and humanities, followed by the natural and mathematical sciences (21.5%), technical and technological sciences (17.6%), philological sciences (7.1%), and medical sciences (6.6%). Four respondents (1%) were from the fields of arts and agriculture, while 5.5% of respondents did not specify the profession to which they belonged. In terms of funding their education, over half of the respondents (45.0%) do so with assistance from the Republic of Serbia's budget, whereas 28.3% do it on their own. 13.9% of respondents said that their doctoral school expenses are covered by their employer, while 10.3% said that their employer and the Republic of Serbia's budget partially finance their studies. 2.5% of respondents mentioned other sources of funding for their doctoral studies. Table 1 displays the sample's professional, academic, and demographic attributes.

Table 1. *Demographic, academic, and professional characteristics of the sample*

	General sample characteristics	
Demographic characteristics	**Gender,** n (%)	
	Male	164 (37.4%)
	Female	274 (62.6%)
	Age (mean value (standard deviation), range)	31.63 (4.81), 21.00 – 45.00
Professional characteristics	**Employment status,** n (%)	
	Employed	404 (92.2%)
	Unemployed	34 (7.8%)
	Length of service (mean value (standard deviation), range)	6.71(4.42), 1.00 – 26.00
Academic characteristics	**Scientific/artistic field,** n (%)	
	Social and Humanities Sciences	179 (40.9%)
	Medical Sciences	29 (6.6%)
	Engineering and Technology Sciences	77 (17.6%)
	Natural and Mathematical Sciences	94 (21.5%)
	Philological Sciences	31 (7.1%)
	Other*	4 (1.0%)
	I was not selected for the position	24 (5.5%)
	Method of funding doctoral studies, n (%)	
	Funded by the Budget of the Republic of Serbia	194 (45.0%)
	Self-Funded by the Student	124 (28.3%)
	Funded by the Budget of the Employing Institution	61 (13.9%)
	Partially Funded by the Budget of the Republic of Serbia and the Employing Institution	45 (10.3%)
	Other	11 (2.5%)

* Due to the small number of respondents (N = 2) in the categories: Art and Agriculture, they were combined into the category "other"

For the purposes of the study, *A questionnaire on the perception and management of stress among doctoral students during their doctoral studies* was created. The questionnaire consists of seven items, with respondents rating their level of agreement on a five-point Likert-type scale (1 - completely agree, 2 - agree, 3 - undecided, 4 - disagree, 5 - completely disagree) for each of them. The items refer to: successful management of stress levels related to doctoral studies; finding constructive ways to reduce the burden of doctoral studies; the emergence of a competitive atmosphere at doctoral studies; time organization in order to continuously engage in doctoral studies; provision of quality free time or relaxation activities; constructive ways of accepting frequent evaluations of personal achievements and finding a balance between academic obligations. The questionnaire was designed to achieve the study's aim, and the metric features were subsequently determined.

The structure of the seven-question questionnaire was examined using factor analysis. The Kaiser-Meyer-Olkin test of sample adequacy was used to assess the reliability of the factor analysis, and the result was 0.840, indicating that the model's factor analysis may be conducted. The correlation between the questions was checked using *Bartlett's Test of Sphericity*. The test resulted in a value of $\chi^2 = 1382.917$ ($p < 0.001$), indicating that factor analysis can examine the questionnaire structure. Only one eigenvalue is greater than one, indicating that a single construct accounts for all seven items. A single factor explained 55.19% of the variance. This one-dimensional questionnaire assesses the ability of doctoral students to manage stress. Factor saturation for all items ranges from 0.828 to 0.616. The reliability is appropriate ($\alpha = 0.858$ to $\alpha = 0.829$), and the overall reliability of the questionnaire is strong ($\alpha = 0.860$). Table 2 presents the results of the factor analysis and reliability analysis.

Table 2. *Results of factor analysis, Varimax rotation*

	Initial *Eigen* values			Factor saturations	Crombach Alpha coefficient
	Total	Variance (%)	Cumulative values		
1	3.863	55.19	55.19	0.828	0,829
2	0.92	13.144	68.334	0.813	0,826
3	0.628	8.975	77.309	0.783	0,858
4	0.596	8.511	85.82	0.718	0,844
5	0.482	6.889	92.708	0.717	0,845
6	0.284	4.051	96.759	0.703	0,846
7	0.227	3.241	100.000	0.616	0,829

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.840, Bartlett's Test of Sphericity = 1382.917 (p < 0,001). α Total = 0,860

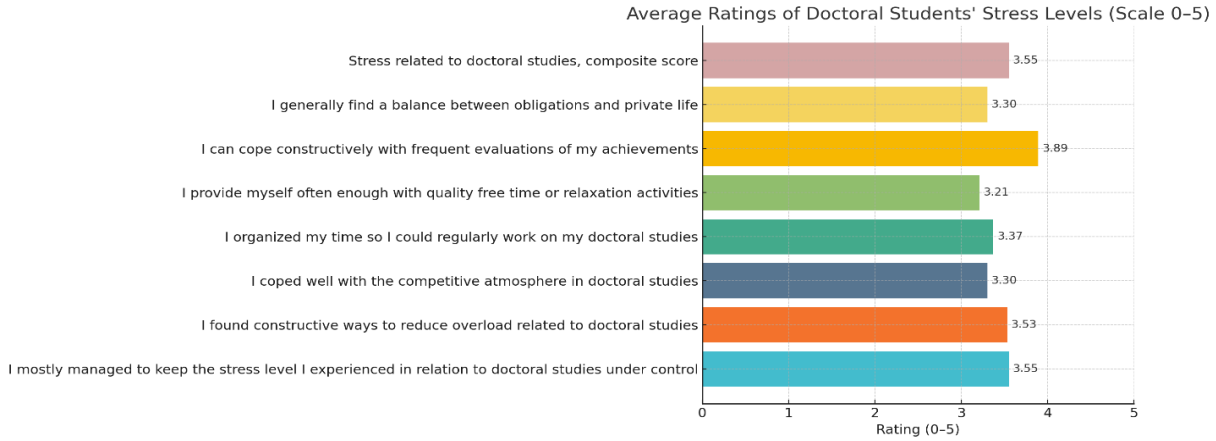
1 = Most of the time, I successfully controlled the level of stress I experienced in connection with doctoral studies, 2 = I found constructive ways to reduce the overload of doctoral studies, 3 = I tolerated well the emergence of a competitive atmosphere during doctoral studies, 4 = I organized my time so that I could regularly engage in my doctoral studies, 5 = I provide myself with sufficient quality free time or relaxation activities, 6 = I can deal constructively with frequent evaluations of personal achievement, 7 = I generally find a balance between obligations and private life.

The dimensionality of the questionnaire was investigated using factor analysis (Varimax rotation), and its reliability was assessed using the Cronbach's alpha coefficient. One-way ANOVA and Student's t-test were used to compare differences between groups. The Pearson correlation coefficient was used to assess the relationship between two numerical variables. The mean value with the appropriate standard deviation was employed to calculate descriptive statistics, whilst qualitative variables were given as frequencies and percentages. Statistical significance was defined as $p < 0.05$ for the null hypothesis. SPSS ver. 24 (*Statistical Package for the Social Sciences*) was used to process and analyze the research results.

Results

To investigate the ability to manage stress among doctoral students during their studies, numerous stress-management factors were examined in relation to the respondents' demographic, professional, and academic characteristics. The similarities and variations in stress management techniques among doctoral candidates with different characteristics were also examined.

The first research objective was to examine the prevalence rate of various stress-managing techniques during doctoral studies, including the ability to manage stress, finding constructive ways to reduce overload, coping with a competitive environment, the effectiveness of time management, the frequency of evaluation of achievements, balancing academic obligations with private life, and the ability to ensure quality free time for relaxation, as well as examining the general level of stress among doctoral students. The study's findings reveal that doctoral students generally manage well in a competitive environment (M = 3.99, SD = 0.99) and with frequent evaluations of their achievements (M = 3.89, SD = 0.90), perceiving these characteristics as less stressful. In contrast, the study results show that doctoral students feel more pressure in the segments related to controlling the level of stress experienced during their studies (M = 3.53, SD = 1.09), organizing their time (M = 3.37, SD = 1.26), and establishing a balance between academic obligations and their private life. While some PhD students successfully apply stress-reduction measures, others face significant difficulty in effectively managing these aspects (M = 3.53, SD = 1.10). It is crucial to note that doctoral students experience more difficulty in acquiring quality free time or engaging in relaxation activities (M = 3.21, SD = 1.35), resulting in insufficient time for rest and relaxation. The collected research findings show that the aforementioned elements imply a moderate level of stress management among PhD students (M = 3.55, SD = 0.84). Graph 1 illustrates the average ratings of various stress-related behaviours throughout PhD studies, as well as the overall average score of doctoral students' abilities to apply them.



Graph 1. Average perceptions of the stress-managing behaviours among PhD students

With regard to various demographic, professional, and academic characteristics of doctoral students (gender, work status, belonging to a certain scientific or artistic field, financing methods), the second research task aims to ascertain the differences in the level of success of using the named stress managing techniques (ability to manage stress, finding constructive ways to reduce overload, coping with a competitive atmosphere, efficiency of time management, frequency of evaluation of achievements, balancing academic obligations with private life, and the ability to ensure quality free time for relaxation).

Differences in respondents' judgments according to gender are evident in the examination of research findings on stress perception and stress management in PhD studies. In the areas of stress management and identifying productive strategies to lessen overload during coursework or thesis work, statistically significant gender disparities are evident. While female doctoral students exhibit a higher level of overall stress management ($M = 3.39$, $SD = 1.13$, $p < 0.01$) and find constructive ways to reduce overload ($M = 3.43$, $SD = 1.16$, $p < 0.01$), male doctoral students are more capable to control their stress level ($M = 3.78$, $SD = 0.99$, $p < 0.01$). No statistically significant gender differences were found in other stress-managing segments, such as managing a competitive environment, scheduling time, guaranteeing quality free time, constructively handling frequent evaluations of accomplishments, and creating a balance between responsibilities and personal life.

The research findings regarding differences in various aspects of stress management based on the employment status of the respondents indicate statistically significant differences between PhD students who are employed and those who are not, for the majority of studied factors. The statistical evidence supports the aforementioned claim that unemployed doctoral students are better able to handle the stress of their studies ($M = 4.12$, $SD = 0.95$, $p < 0.01$), find positive ways to reduce overload ($M = 4.03$, $SD = 0.97$, $p < 0.01$), learn how to manage the time needed to complete their studies ($M = 4.44$, $SD = 0.75$, $p < 0.01$), ensure quality leisure time ($M = 4.09$, $SD = 1.06$, $p < 0.01$), and balance their personal and professional commitments ($M = 4.00$, $SD = 1.10$, $p < 0.01$). However, when it came to managing the competitive environment and overcoming the regular evaluations of accomplishments required by PhD studies, the investigation revealed no statistically significant differences between employed and unemployed doctoral students. Regardless of the examinees' employment position, the challenges related to these areas of PhD study are common and equally severe.

There are statistically significant disparities in doctoral students' capacities to navigate a competitive environment, according to an analysis of respondents' perceptions of stress associated with doctoral studies across various scientific and artistic professions. Compared to those in other scientific or artistic disciplines, doctoral students in the scientific field of medical sciences ($M = 4.17$, $SD = 0.93$, $p < 0.05$) and those not elected to the title ($M = 4.17$, $SD = 0.87$, $p < 0.05$) are better able to handle the stresses of competition. On the other hand, in light of the prevailing competitive atmosphere during doctoral studies, respondents from the scientific discipline of Philological Sciences ($M = 3.58$, $SD = 1.29$, $p < 0.05$) exhibit a lower level of stress management. Doctoral students, coming from various domains report varying degrees of coping skills, including the Natural Sciences ($M = 3.77$, $SD = 1.07$, $p < 0.05$), Engineering and Technology Sciences ($M = 4.12$, $SD = 0.87$, $p < 0.05$), and Social Sciences ($M = 4.08$, $SD = 0.94$, $p < 0.05$). However, they are more skilled in coping techniques than those in the Philological Sciences. The

respondents classified as "other" (Art and Agriculture) exhibit a moderate level of stress management ($M = 3.75$, $SD = 1.26$, $p < 0.05$). No statistically significant differences were found among doctoral students of different scientific and artistic fields in other stress-management behaviors, such as time management, providing quality free time, frequency of achievement evaluations, effectiveness of managing stress related to studies, finding constructive ways to reduce overload, and balancing professional and private obligations. This suggests that these challenges have an equal impact on the presence of stress in all doctoral students, regardless of their specific academic discipline.

Statistically significant differences in stress management are observed concerning the method of financing doctoral studies, particularly in the areas of time management, maintaining quality free time, and balancing professional and personal obligations. Doctoral students funded by the Republic of Serbia's budget experience the highest stress-management abilities related to time management in meeting the demands of their doctoral studies ($M = 3.58$, $SD = 1.27$, $p < 0.05$). PhD students who receive partial funding from the Republic of Serbia's budget and/or their employer report slightly lower abilities in time management ($M = 3.02$, $SD = 1.25$, $p < 0.05$), indicating that combining multiple funding sources does not make time management any easier. The somewhat lower time management ability among self-financing students ($M = 3.22$, $SD = 1.21$, $p < 0.05$) could be a result of extra financial strains that make time management challenging. Doctoral students who receive funding from their employer's budget exhibit even more reduced stress-managing ability ($M = 3.30$, $SD = 1.24$, $p < 0.05$), indicating that time management remains challenging even with a steady income. Lastly, the group of PhD students who received funding from "other different ways" reported stress-managing levels that were comparable to those of self-funded students ($M = 3.27$, $SD = 1.35$, $p < 0.05$). This suggests that various unconventional funding sources can have comparable impacts on time management. When it comes to methods of funding doctoral studies, statistically significant variations in stress management are visible in the area of achieving quality leisure time. When it comes to planning their spare time, doctoral students who have alternative sources of funding report the highest score ($M = 3.73$, $SD = 1.27$, $p < 0.05$), which suggests that they have more time to relax and fewer demanding responsibilities. Furthermore, a major factor in reducing stress associated with time management is the financial stability of doctoral students, which is derived from funds allocated to their institution's budget ($M = 3.41$, $SD = 1.46$, $p < 0.05$). Although budget money ($M = 3.36$, $SD = 1.32$, $p < 0.05$) offers some assurance, free time management might still be challenging due to academic commitments. The lowest level of leisure time quality is experienced by self-funded PhD students ($M = 2.88$, $SD = 1.34$, $p < 0.05$), suggesting that financial difficulties may severely restrict their leisure time. Doctoral students who receive partial funding from the Republic of Serbia's and/or the institution's budgets ($M = 3.07$, $SD = 1.32$, $p < 0.05$) struggle to manage their free time; even with partial funding, they find it challenging to plan leisure activities. There were also statistically significant differences in the balancing of personal and professional commitments among PhD students based on the financing strategy. Doctorate students with various unconventional sources of funding exhibit the highest scores in this segment ($M = 3.64$, $SD = 1.12$, $p < 0.05$), suggesting that these sources of funding offer them more flexibility or extra resources that help them better balance their personal and professional commitments. Additionally, PhD students funded by the Republic of Serbia's budget ($M = 3.50$, $SD = 1.28$, $p < 0.05$) report finding a balance between their private lives and responsibilities more challenging. Doctoral students who get funding from their employer's budget report significantly lower scores ($M = 3.20$, $SD = 1.29$, $p < 0.05$), suggesting that while institutional funding can offer some stability, it can still present difficulties in balancing commitments. Similar to this, doctoral students who receive partial funding from both the Republic of Serbia's budget and their employer report an average score ($M = 3.18$, $SD = 1.17$, $p < 0.05$), indicating that it can be challenging to manage responsibilities when funding comes from several sources. Self-funded PhD students, on the other hand, report the lowest levels of balance ($M = 3.06$, $SD = 1.11$, $p < 0.05$), indicating that financial strain significantly impairs their ability to strike a balance between personal and professional obligations. Additionally, research findings on funding did not reveal statistically significant differences in how doctoral students cope with a competitive environment, find constructive ways to reduce overload, and manage frequent evaluations of their accomplishments.

There is a significant correlation between the age of the respondents and the ability to manage stress. Specifically, a substantial negative correlation ($r = -0.166$, $p < 0.01$) confirms that older PhD students are less likely to provide quality leisure time or relaxation activities. According to these findings, older PhD candidates struggle more to find time for rest and relaxation, which may be a contributing factor

to their elevated stress levels. However, there was no significant correlation found between the length of job experience and any particular component of stress management ability (the ability to manage stress, find constructive ways to reduce overload, deal with a competitive atmosphere, the effectiveness of time management, the frequency of evaluation of achievements, balancing academic obligations with private life, and the ability to ensure quality free time for relaxation), indicating that it is not a significant factor in determining how PhD students manage stress. Correlations between length of service and stress management ability are very low and not statistically significant ($p > 0.05$) ($r = 0.05$ for stress level control, $r = 0.049$ for finding constructive ways to reduce pre-load, $r = 0.034$ for coping with a competitive atmosphere, $r = 0.021$ for time management, $r = -0.094$ for ensuring quality free time, $r = -0.028$ for constructive behavior with frequent evaluation of achievements, $r = -0.024$ for balancing duties and private life).

Table 3 displays the results concerning the relationship between the age and the duration of work experience of the respondents and theeur ability to cope with the specific stressors.

Table 3. *Differences in doctoral students' levels of particular stress-management factors according to their academic, professional, and demographic traits, as well as the correlation between these factors and the students' ages and duration of work experience*

	Stress-management factors during doctoral studies						
General characteristics of the respondents	1	2	3	4	5	6	7
	M(SD)	M(SD)	M(SD)	M(SD)	M(SD)	M(SD)	M(SD)
Gender (p)[a]	**< 0,01**	**< 0,01**					
Male	3.78(0.99)	3.71(1.00)	4.04(0.96)	3.45(1.22)	3.25(1.36)	3.99(0.86)	3.29(1.21)
Female	3.39(1.13)	3.43(1.16)	3.96(1.01)	3.33(1.28)	3.18(1.36)	3.83(0.93)	3.31(1.24)
Employment status (p)[a]	< 0.01	< 0.01		< 0.01	< 0.01		< 0.01
Not employed	4.12(0.95)	4.03(0.97)	3.97(0.97)	4.44(0.75)	4.09(1.06)	4.18(1.00)	4.00(1.10)
Employed	3.49(1.09)	3.49(1.11)	4.00(1.00)	3.28(1.26)	3.13(1.36)	3.87(0.89)	3.25(1.22)
Scientific/artistic field (p)[b]			**< 0.05**				
Social and humanities	3.55(1.13)	3.58(1.14)	4.08(0.94)	3.32(1.27)	3.13(1.36)	3.93(0.85)	3.30(1.18)
Medical sciences	3.76(1.06)	3.59(1.05)	4.17(0.93)	3.52(1.21)	3.21(1.24)	3.72(1.16)	3.45(1.18)
Technical and technological sciences	3.61(1.02)	3.48(1.07)	4.12(0.87)	3.36(1.22)	2.96(1.39)	3.79(0.95)	3.12(1.25)
Natural and mathematical sciences	3.32(1.12)	3.45(1.09)	3.77(1.07)	3.45(1.29)	3.39(1.30)	3.86(0.86)	3.30(1.29)
Philological sciences	3.35(1.14)	3.26(1.18)	3.58(1.29)	3.10(1.27)	3.19(1.40)	3.77(1.09)	3.26(1.26)
Other*	3.25(0.96)	3.25(0.96)	3.75(1.26)	3.25(1.50)	3.25(2.06)	4.25(0.96)	3.50(1.91)
Not appointed	4.04(0.81)	4.04(1.00)	4.17(0.87)	3.71(1.27)	3.83(1.34)	4.33(0.64)	3.83(1.20)
Method of funding doctoral studies (p)[b]				**< 0.05**	**< 0.05**		**< 0.05**
Funded by the Budget of the Republic of Serbia	3.54(1.13)	3.51(1.16)	4.06(0.99)	3.58(1.27)	3.36(1.32)	3.95(0.93)	3.50(1.28)
Self-Funded by the Student	3.53(1.02)	3.56(0.96)	3.94(0.94)	3.22(1.21)	2.88(1.34)	3.74(0.88)	3.06(1.11)
Funded by the Budget of the Employing Institution	3.59(1.19)	3.61(1.16)	4.00(1.05)	3.30(1.24)	3.41(1.46)	4.07(0.89)	3.20(1.29)
Partially Funded by the Budget of the Republic of Serbia and the Employing Institution	3.44(1.06)	3.36(1.21)	3.87(1.01)	3.02(1.25)	3.07(1.32)	3.73(0.86)	3.18(1.17)
Other	3.45(1.13)	3.82(0.98)	3.82(1.33)	3.27(1.35)	3.73(1.27)	4.09(0.83)	3.64(1.12)
	r	**r**	**r**	**r**	**r**	**r**	**r**
Age (p)[c]	-0.041	-0.026	-0.02	-0.058	**-0.166****	-0.067	-0.091
Years of employment service (p)[c]	0.05	0.049	0.034	0.021	-0.094	-0.028	-0.024

Stress-menagement factors: 1 = Most of the time, I successfully kept under control the level of stress I experienced in connection with doctoral studies, 2 = I found constructive ways to reduce the overload of doctoral studies, 3 = I coped well with the emergence of a competitive atmosphere during my doctoral studies, 4 = I organized my time in a way that allows me to focus on my doctoral studies regularly, 5 = I provide myself with enough quality free time or relaxation activities, 6 = I can deal constructively with frequent evaluations of my achievement, 7 = I generally find a balance between obligations and private life. Abbreviations: M (SD) = mean (standard deviation), r = Pearson correlation coefficient.

[a]Student's t test; [b]ANOVA test; [c]Pearson correlation coefficient
** Statistical significance at the < 0.01 level
The table shows values of p ≤ 0.05

The obtained research results demonstrate the existence of significant differences in the general ability to manage stress among doctoral students. The examined differences were related to doctoral students in regard to demographic, professional, and academic characteristics (gender, work status, belonging to a particular scientific or artistic field, and methods of financing). Although male respondents reported slightly higher levels of stress management (M = 3.64, SD = 0.78) compared to female doctoral students (M = 3.49, SD = 0.88), generally, coping with potential stress can not be attributed to gender differences. The degree of stress management varied statistically significantly based on employment status, with unemployed respondents demonstrating a higher capacity to manage stress during doctoral studies (M = 4.12, SD = 0.73) than employed doctoral students (M = 3.50, SD = 0.84), p < 0.01. The stress management associated with doctoral studies is similar for PhD students in the following scientific and artistic fields: Philological sciences (M = 3.36, SD = 0.92), Natural and Mathematical Sciences (M = 3.50, SD = 0.84), Medical Sciences (M = 3.63, SD = 0.92), Technical and Technological Sciences (M = 3.49, SD = 0.82), Social and Humanities (M = 3.55, SD = 0.83), the category "other" (Art and Agriculture) (M = 3.50, SD = 1.32), and those who were not appointed (M = 3.99, SD = 0.69). There are no statistically significant differences between PhD students who receive different forms of funding; however, those who self-finance (M = 3.42, SD = 0.80) and those who receive partial funding from the Republic of Serbia's and the institution's budget (M = 3.38, SD = 0.83) reported lower levels of stress management. In contrast, respondents who receive funding from the Republic of Serbia's budget (M = 3.64, SD = 0.87) and those who have "other different ways of financing" (M = 3.69, SD = 0.65) reported the highest levels of coping with stress. These variations are not statistically significant, though.

Table 4. *Differences in doctoral students' overall stress coping across various demographic, professional, and academic traits, as well as the correlation between overall stress coping and doctoral students' age and length of work experience*

General characteristics of the respondents	Stress related to PhD studies, total
Gender (p)[a]	**M (SD)**
Male	3.64 (0.78)
Female	3.49 (0.88)
Employment status (p)[a]	**< 0.01**
Not employed	4.12 (0.73)
Employed	3.50 (0.84)
Scientific/artistic field (p)[b]	
Social and humanities	3.55 (0.83)
Medical sciences	3.63 (0.92)
Technical and technological sciences	3.49 (0.82)
Natural and mathematical sciences	3.50 (0.84)
Philological sciences	3.36 (0.92)
Other*	3.50 (1.32)
Not appointed	3.99 (0.69)
Method of funding doctoral studies (p)[b]	
Funded by the Budget of the Republic of Serbia	3.64 (0.87)
Self-Funded by the Student	3.42 (0.80)
Funded by the Budget of the Employing Institution	3.59 (0.87)
Partially Funded by the Budget of the Republic of Serbia and the Employing Institution	3.38 (0.83)
Other	3.69 (0.65)
	r
Age (p)[c]	**-0.096***
Years of employment service (p)[c]	-0.002

Abbreviations: M (SD) = mean (standard deviation), r = Pearson correlation coefficient
[a]Student's t test; [b]ANOVA test; [c]Pearson correlation coefficient
* Statistical significance at the level < 0.05
The table shows values of p ≤ 0.05

The relationship between PhD students' overall stress management ability and their age and length of job experience was also analyzed as part of the study. According to the study's findings, older PhD candidates experience greater difficulty coping with stress related to their studies ($r = -0.096$, $p < 0.05$), whereas there was no significant correlation between stress levels and the length of job experience ($r = -0.002$, $p > 0.05$). According to these results, doctoral students' abilities in stress management are more significantly influenced by age as a demographic component than by professional experience.

Table 4 presents the findings from the analysis of variations in overall stress coping among PhD candidates with diverse demographic, professional, and academic characteristics. It also shows the correlation between the overall stress coping during PhD studies and the students' age and length of work experience.

Discussions

The study's objective was to investigate how PhD students experience stress, and it identified the ways students manage stress while pursuing their degrees. The established patterns, as determined by statistical results, validate that a variety of institutional, professional, and individual factors influence doctoral students' perceptions and stress levels (Bair and Haworth, 2004; Gardner, 2009; Barry et al., 2018).

The multifaceted nature of the stress management experience for doctoral students is illustrated by the examination of the manifestation of several stress-management behaviours throughout their doctoral studies. A high degree of competence in handling a competitive environment and regular performance reviews demonstrates that PhD students can effectively manage their stress levels in these areas, even in the face of a competitive setting and ongoing evaluations. However, there is a greater emphasis on managing stress through time management and finding a balance between personal and academic commitments. These factors are significant sources of coping with stress for PhD students. According to statistical data, the need to improve time management abilities and, consequently, reduce stress levels should be highlighted. For doctoral students, finding productive strategies to reduce overload and guarantee quality free time also presents obstacles. Although some PhD students are able to apply stress-reduction techniques successfully, many still struggle significantly with these areas. Research indicates that doctoral students often lack sufficient time for rest and relaxation, which has a detrimental impact on their overall and mental well-being. The results obtained support earlier studies that show doctoral students are resilient to academic stress, despite competition and frequent evaluations. Time constraints and overload continue to be major obstacles in managing stress, particularly for those balancing work and personal commitments (Jairam and Kahl, 2012; Cotton et al., 2017; Schmidt and Hansson, 2018; Sverdlik et al., 2018). Overall, the study's findings indicate that doctoral students deal with stress moderately ($M = 3.54$, $SD = 0.84$), suggesting that while they are able to manage certain aspects of stress effectively, there are still important issues that need further attention. The hypothesis, which holds that doctoral students who manage their time better deal with stress more easily, was partially confirmed based on the research findings. Time management has been recognized as a key stressor, which further supports its significance in lowering the feeling of stress, even if it is not the only factor that impacts the overall amount of stress among PhD students.

The analysis of the research findings reveals significant differences among respondents with varying demographic, professional, and academic characteristics in their perception and management of stress through stress-management techniques in the context of doctoral studies. First, based on the respondents' gender-based evaluations, male PhD students are better able to manage their stress levels and discover healthy strategies to reduce their study overload, whereas female PhD students exhibit lower levels of stress management in the aforementioned segments. According to earlier studies, women are more prone to stress due to their emotional sensitivity, adherence to gender norms, and the challenge of balancing work and personal commitments (Stubb et al., 2012; Watson and Watson, 2016; Cotton et al., 2017; Schmidt and Hansson, 2018; García-Martínez et al., 2021). These data support these findings. Other stress-management factors, such as managing a competitive environment, organizing time, guaranteeing quality leisure time, coping with frequent appraisals of accomplishments, and striking a balance between academic responsibilities and personal life, did not show statistically significant gender differences. This data supports the gender-disparities portion of the hypothesis, which states that female PhD students find it harder to manage stress. It also emphasizes the necessity of specific guidance techniques for female PhD students in order to lower their stress levels. The level of adaptability of both genders in a competitive setting disagrees with previous research, which suggests that men are more resilient to pressures from competition (Schmidt and Hansson, 2018).

The study's findings reveal that employed and unemployed doctoral students perceive stress in distinctly different ways. Compared to PhD students who were employed, unemployed students showed greater efficacy in managing study-related stress, identifying positive strategies to reduce overload, time management, finding free time, and balancing work and personal commitments. These findings align with earlier studies that have found unemployed PhD students to be better organized and experience less stress, as they have more time and flexibility to devote to their academic obligations (Sverdlik et al., 2018; Barry et al., 2018). However, doctoral students who are employed encounter additional difficulties because of their work commitments, which results in a shortage of time and resources for both academic work and appropriate stress management. Maintaining a balance between work and studies was identified as a major issue for this set of respondents, and this study demonstrates that it is challenging due to the combination of professional and academic expectations. However, no statistically significant differences were found between employed and unemployed doctoral students in the sections on overcoming frequent evaluations of accomplishments and dealing with a competitive atmosphere. This suggests that these challenges are universal regardless of employment status (Cotton et al., 2017; Schmidt and Hansson, 2018). The section of the hypothesis that predicts a lower level of stress management among unemployed doctorate students is rejected by the aforementioned findings, which imply that unemployed doctoral students show higher level of stress management due to better flexibility and resource availability.

According to the study's findings, PhD students' perceptions of stress management vary significantly depending on how they intend to pay for their education. The results of previous studies on the significance of financial stability in reducing academic pressure are supported by the fact that doctoral students funded by the Republic of Serbia's budget report better coping with stress in terms of time management and balancing obligations (Lovitts, 2001; Cotton et al., 2017). Self-funded PhD students, on the other hand, find it harder to manage stress in every area studied, suggesting that financial insecurity presents additional challenges (Barry et al., 2018; Sverdlik et al., 2018). The results for PhD students who receive partial funding from their own budget or the budget of the organization where they work are especially intriguing because they show the lowest degree of time management. According to this research, balancing many sources of funding might make academic work much more challenging and make it more difficult to manage obligations. Doctorate students with alternative funding sources report less stress while balancing their personal and professional commitments, which may be a sign of more flexibility or more resources offered by this type of support (Stubb et al., 2012). However, the hardest time in stress management in this segment is reported by PhD students who finance themselves and those who share funding sources, which supports earlier findings about the detrimental effects of financial insecurity on the capacity to balance personal and professional commitments (Sverdlik et al., 2018). Doctoral students who receive funding from their employer's budget report to experience fewer concerns when it comes to finding quality free time, demonstrating the stability this type of funding offers. On the other hand, self-funded PhD students report the lowest level of stress management, which can be because of their continuous financial and academic commitments that limit their free time. These results are in line with studies by Cotton et al. (2017), which emphasize how crucial institutional support is for reducing academic stress. The results did not reveal statistically significant differences between groups of doctoral students in the areas of managing stress levels, identifying healthy strategies to lessen overload, navigating a competitive environment, and regularly evaluating accomplishments. This may suggest that, as prior research has shown, these factors are generally stressful for PhD students, irrespective of the funding source (Jairam and Kahl, 2012; Schmidt and Hansson, 2018). The part of the hypothesis related to the method of funding is supported by findings indicating that financial insecurity significantly lowers the level of stress management ability among PhD students, which is consistent with the results of previous research (Lovitts, 2001; Cotton et al., 2017; Sverdlik et al., 2018).

The findings of how PhD students in various scientific and artistic disciplines manage stress show notable variations in their capacity to handle a competitive environment. While PhD students in the Philological Sciences find it harder to cope in the aforementioned area, doctoral students in the Medical Sciences and those who were not selected for the title handle competing pressures better than others. These results emphasize the significance of specialized techniques and strategies to support PhD students by pointing to particular requirements and obstacles within each academic subject. No statistically significant differences were found among doctoral students of various scientific and artistic fields in other stress-managment segments, such as time management, ensuring quality free time, dealing with frequent evalu-

ations of accomplishments, the effectiveness of stress management, and balancing professional and private obligations. This suggests that these challenges are universal regardless of the academic discipline. While the individualized nature of research and reliance on subjective evaluations of results in other fields can increase the level of stress (Cotton et al., 2017; Schmidt and Hansson, 2018), the established differences in prior research indicate specific challenges and needs within each academic discipline, highlighting the fact that teamwork and professional discipline characteristics of the medical field can reduce stress among doctoral students (Vekkaila et al., 2013; Sverdlik et al., 2018). Since it was not found that, aside from the appearance of a competitive atmosphere, doctoral students' stress levels are significantly impacted by their affiliation with a particular scientific or artistic field, part of the hypothesis that says that affiliation does not have a significant effect on the perception of stress was partially confirmed.

In conclusion, it was partially confirmed that there are statistically significant differences in how doctoral students manage stress across various demographic, professional, and academic characteristics. Specifically, female doctoral students, those without employment, and students who finance themselves find it harder to manage stress, while belonging in a particular scientific or artistic field has no discernible impact on stress perception. The respondents' employment status revealed results that were contrary to expectations, even though the influence of gender differences and funding methods on the presence of coping behaviours among doctoral students was confirmed. The influence of belonging to a particular scientific or artistic field was also partially confirmed, with statistical significance only noted when dealing with a competitive atmosphere.

The study's findings about the link between doctoral students' age and length of work experience and coping with stressful aspects of their studies show a strong correlation between respondents' age and stress management ability. In particular, a significant negative correlation ($r = -0.166$, $p < 0.01$) indicates that older PhD students are less likely to engage in quality leisure time or relaxation activities, which may lead to elevated stress levels. These findings are consistent with earlier studies that show older PhD students have less schedule flexibility and greater constraints when it comes to planning leisure time because of work and family commitments (Sverdlik et al., 2018). Nevertheless, there was no discernible correlation between the duration of work experience and any particular stress management behaviour. Doctoral students' stress management behaviors and the duration of their work experience had very weak and statistically negligible correlations. According to these results, doctoral students' responses to stress are not significantly influenced by length of service, suggesting that this aspect of the hypothesis is not supported by empirical evidence. Furthermore, Cotton et al. (2017) found that PhD students' stress is caused by the demands of their studies rather than by their prior work experience. In summary, the hypothesis that the age and length of work experience of doctoral students are correlated to managing stressful aspects of their studies was partially confirmed. It is assumed that older doctoral students and those with more extensive work experience tend to have higher levels of stress.

The study's findings shed important light on how the general stress levels of doctoral students differ depending on their academic, professional, and demographic characteristics. First, the research findings do not support the section of the hypothesis that deals with gender differences in doctoral students' stress management. Stress management levels were marginally greater among male respondents than among female respondents, but the differences were not statistically significant. While certain factors like emotional sensitivity and social roles can lead to gender differences in the perception of certain stressors, the findings are consistent with earlier research showing that academic stress is universal among doctoral students, regardless of gender (Cotton et al., 2017; Schmidt and Hansson, 2018). Because statistically significant variations were observed in the stress responses of employed and unemployed doctoral students, part of the hypothesis regarding the working status of PhD students was validated. According to the findings, PhD students who are unemployed report better stress management because they have more flexibility and time to dedicate to their studies, whereas PhD students who are employed balance their professional and academic responsibilities, which reduces their stress management abilities. The results of Jairam and Kahl (2012), who highlight the significance of time and flexibility in the successful completion of doctoral studies, and Sverdlik et al., (2018), who noted that additional professional obligations for employed doctoral students increase the level of stress, are both supported by a statistically significant difference in stress management between employed and unemployed doctoral students ($p < 0.01$). According to the findings, doctoral students in various scientific or artistic fields had similar average stress management behaviors, and the differences in stress management between these groups were not statistically significant. This suggests that doctoral students' overall stress levels are not significantly

impacted by their affiliation with a scientific or artistic field. Within the hypothesis, it was confirmed that there were no appreciable differences in stress management across PhD students from various scientific and creative disciplines. According to this research, stressors are present in all academic domains, meaning that PhD candidates in other fields face comparable difficulties while pursuing their degrees. There was no evidence to support the notion that students who finance their own education experience higher levels of stress than those who receive funding from the Republic of Serbia's budget. But, the results showed that self-funded students and those partially funded from the budget of the RS reported lower levels of stress management, whereas those who received funding from the RS budget and those who had other sources of funding reported better handling of stress management behaviours. Although the changes were not statistically significant, the results suggest that stress management may become harder in response to financial strains, but not to the extent that the financing method significantly affects overall stress management. This result aligns with research by Barry et al. (2018) and Lovitts (2001), which suggests that while financial stability may mitigate certain stressors, it does not entirely eliminate the common stressors associated with PhD studies. Regarding various demographic, professional, and academic characteristics, the hypothesis that there are statistically significant differences in the general stress management among doctoral students was partially confirmed. It was assumed that female doctoral students who are employed and self-financed exhibit a lower level of stress management, while differences are not recorded among doctoral students of different scientific or artistic fields. According to these findings, doctoral students' stress management abilities vary statistically significantly based on their employment status; however, there were no statistically significant differences in stress management according to gender, financing method, or affiliation with the scientific or artistic community.

The study's findings provide an empirical foundation for testing the hypothesis that there is a statistically significant relationship between age and length of work experience, as well as overall stress, in the context of doctoral studies. The findings indicated that the respondents' age and stress coping ability had a strong negative correlation ($r = -0.096$, $p < 0.05$), suggesting that older PhD students find it harder to apply stress magement behaviours. This result validates the portion of the hypothesis concerning PhD students' ages. With increased work and family obligations, as well as other challenges, older PhD students may struggle to balance their studies with other aspects of their lives, which further exacerbates their stress levels. However, there was no statistically significant correlation between the duration of job experience and overall stress management ($r = -0.002$), which lends support to the theory that work experience has no discernible effect on PhD students' stress management techniques. This finding can be explained by the fact that, in the context of doctoral studies, work experience does not always translate into improved stress management abilities. Instead, other factors-like personal coping mechanisms and the support doctoral students receive-are more crucial in lowering the stress levels of doctoral candidates. According to the hypothesis, the study's findings support the idea that older PhD candidates feel higher levels of stress overall, but there is no discernible correlation between stress perception and the duration of job experience.

Conclusions

The primary hypothesis of the study, according to which PhD students experience difficulties in managing stress while pursuing their degrees, was validated. The findings demonstrated that doctoral students experience considerable stress, regardless of their varying demographic, professional, and academic characteristics. This suggests that there are common difficulties and stressful elements that arise throughout PhD study. Although specific characteristics, such as work status, had a specific impact on the ability to manage stress, we assumed that a general trend of high stress was present in all groups of doctoral students, which highlights the need for a comprehensive approach to student support during doctoral studies. These results suggest that stress is a pervasive issue that warrants systematic interventions to enhance the academic experience and reduce stress levels among all PhD students, rather than being limited to specific groups. Universal stressogenic factors, such as high academic expectations, time pressures, and frequent evaluations, remain important sources of stress (Kordić, 2023). In addition, the psychological well-being of doctoral students also depends on the institutional environment and support, whereas unfavorable academic expectations might result in burnout and exhaustion (Maluckov, 2018). PhD students' varying stress levels are caused by a variety of stressors, which have an immediate impact

on their mental health and stress management ability. The completion of education and future professional direction may become more uncertain, leading to anxiety as a result of these circumstances.

The findings of the study indicate that in order to reduce stress and enhance doctoral students' academic experiences, an encouraging academic atmosphere must be established. Academic standards should be more flexible, time management skills should be enhanced, and institutions should promote mental wellness. Doctoral students' ability to balance their personal and academic lives depends on their perception of the academic environment, highlighting the necessity of institutional support through organizational programs, mentoring, and stress-coping mechanisms (Pyhältö et al., 2012; Lonka and Ketonen, 2019; Mulyati et al., 2023). Some authors (Miltojević et al., 2022) draw attention to the issue of burnout among technical faculty students, while Simić and Vranješević (2022) note the particular difficulties faced by sensitive categories of PhD students, such as those from marginalized populations. Doctoral students' academic and psychological well-being can be enhanced by specially designed support programs, such as courses on time management and stress management. Strategies for coping with the academic difficulties that PhD students experience are important in addition to institutional support measures. Research indicates that PhD students' academic and psychological well-being can be enhanced by flexible academic time management, stress management classes, and increased mentor participation (Milovanović et al., 2023). Additionally, financial assistance can reduce certain types of stress and enhance PhD students' commitment to their research, especially when financial security alleviates pressure and allows for better focus and academic engagement (Levecque et al., 2017; Barry et al., 2018; Sverdlik et al., 2018).

This study's shortcomings include the respondents' subjective assessments of stress management, which could compromise the accuracy of the findings, and the exclusion of key academic and cultural settings from the sample. Furthermore, not all possible stress-management factors have been examined, including institutional regulations and the particular possibilities of particular scientific domains. The aforementioned conditions limit the broad applicability of the findings, but they also underscore the need for further study. Recommendations are provided to lessen stress and enhance doctoral students' academic experiences based on the research that has been done. To help doctoral students better handle academic problems, time management skills must be improved in the direction of more flexible academic standards, which highlights the necessity of institutional support through organizational programs, mentoring, and stress coping mechanisms (Posselt, 2018). The use of technological solutions, such as mobile applications for time management, has been shown to be effective in supporting students' self-organization and reducing stress levels (Alhasani and Orji, 2023; Malik et al., 2024). At the same time, enhancing the role of mentors through training and resources to provide high-quality support is essential to improving the academic experience. The introduction of mental health programs, such as mindfulness training, relaxation techniques, and group support, can greatly contribute to lowering stress and improving the general well-being of aspiring doctors (Mulyati et al., 2023). Furthermore, granting PhD students financial assistance and reliable support networks might lessen additional pressure and free them up to concentrate more on their academic obligations. It is advised to carry out longitudinal research to track shifts in stress perception during the course of PhD studies and assess how well stress-reduction techniques work.

In conclusion, the results of this research highlight the need for a comprehensive approach to supporting doctoral students, including the specific challenges faced by certain groups, in order to effectively reduce stress levels and personal well-being. The research results point to the need to create a supportive academic environment that will reduce stress and improve the academic experience of doctoral students.

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Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, A.S.S., T.M.Đ., A.S., B.N.C, I.T.M., S.M.; methodology, A.S.S., T.M.Đ., A.S., B.N.C, I.T.M.; software, B. N. C.; formal analysis, A.S.S. and T.M.Đ.; writing—original draft preparation, A.S.S., T.M.Đ., A.S., B.N.C, I.T.M., S.M.; writing—review and editing, A.S.S., T.M.Đ., A.S., B.N.C, I.T.M., S.M. All authors have read and agreed to the published version of the manuscript.

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Assessing Decision-Making Skills in Electricity: Rasch Analysis

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Abstract: Decision-making is an essential 21st-century skill, and this is evidenced by the fact that the skill has increasingly gained attention in the current educational landscape. Accordingly, among the various competencies assessed by PISA, decision-making has been observed to be at the top of the list. This skill is particularly important, especially considering the fact that it provides college graduates with a competitive edge in the current workforce. Despite its significance, little work has been carried out to measure decision-making in the context of physics education using Rasch analysis. Therefore, this study aimed to explore the decision-making skills of prospective science teachers, with particular attention to differences based on gender and domicile. In order to achieve the stated objective, a quantitative study method was adopted, with the inclusion of 172 prospective science teachers who had received basic physics. Accordingly, data were collected using a paper-based test technique, which included six questions related to decision-making skills. The physics material utilized during the course of the study includes dynamic electricity, and in terms of the determination of validity and reliability, as well as item difficulty and differences in decision-making skills based on gender and domicile of the prospective science teacher, the Rasch measurement approach was adopted. The obtained results showed that no items could be reviewed based on gender and domicile of the observed prospective science teachers. However, a significant difference was found between the decision-making skills of participants based on gender. Following the observations, the decision-making skills of females were better than those of males, regardless of domicile. In conclusion, the decision-making skills instrument was observed to be valid and reliable. Additionally, the investigation possesses some implications for science educators in the aspect of determining differentiated physics learning designs that accommodate the abilities of students based on gender.

Keywords: *decision-making skills, gender, physics learning, prospective teacher, rasch analysis.*

Introduction

Decision-making skills are a very important requirement across diverse professions and have been observed to play an essential role in realizing citizen awareness of the dimensions of life and the development of sustainable education (Khishfe, 2012; León et al., 2020). Decision-making skills correlate with students' 21st-century skills (Erbas et al., 2025). This study contributes to the sustainable development goals of quality, inclusive, equitable, and gender-equal education (SDGs 4 and 5). Accordingly, theories related to decision-making have been applied across various disciplines, including education, medicine, computer science, mathematics, psychology, nursing, and physics (Kinskey and Zeidler, 2024; Sadeghi et al., 2024; Smoliński and Brycz, 2024; Tutticci and Huss, 2025; Erbas et al., 2025; Yang et al., 2024). As stated in previous studies, decision-making is an important 21st-century competence that needs to be practiced and developed by individuals. It often comprises complex analysis, an in-depth understanding of theory, and the application of concepts in the real world. Physicians, epidemiologists, educators, engineers, and poli-

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cymakers have shown interest in decision-making skills (Garg et al., 2023; Goosen and Steenkamp, 2023; Laka et al., 2022; Razaghpoor et al., 2024). Following the report of Orhan and Ataman (2024), accurate decision-making is correlated with both reflective and creative thinking dispositions and is considered a critical factor that can aid individuals in attaining success in the future.

Many studies have shown the importance of decision-making skills in various contexts. For instance, these skills have been found to possess a significant relationship with reasoning (Sakschewski et al., 2014), critical thinking (Wolcott and Sargent, 2021), scientific literacy (Spatz, Tampe, and Slezak, 2019), problem-solving on social scientific issues (Garrecht et al., 2020; Pietrocola et al., 2021), competence and mental health (Bavol'ár and Orosová, 2015), as well as regulating learning (Zhang and Hsu, 2021). In accordance with this, Gresch et al. (2017) found that decision-making strategies integrated with reflective thinking, the decision-making processes, and self-regulation elements were very beneficial in science, technology, society, and environmental education. Another study stated that decision-making skills could be improved through real-world and game-based learning, particularly within the context of nursing students (Vázquez-Calatayud et al., 2024).

Numerous investigations have been conducted across various fields with the aim of developing clinical decision-making instruments within several countries (Lauri and Salanterä, 2002). The subject matter has also been examined within the domain of science education, particularly in countries such as Germany, where the competence was associated with environmental issues (Garrecht et al., 2020). Furthermore, the decision-making abilities and styles of junior high school students have been explored (Novianawati and Nahadi, 2015). Regardless of the diverse reach, these studies often fall short in addressing the skills in a more advanced way among undergraduates. Assessing decision-making skills among university students is crucial, considering the fact that it not only emphasizes the developmental progress of the students but also provides invaluable insight for improving curricula. It is also important to state that the measurements that will be obtained from such assessments could offer educators a clearer understanding of student abilities while equipping students with the skills necessary to thrive in the workforce. This study, in particular, adds to the growing body of knowledge by examining decision-making skills within the context of physics learning among prospective teachers in higher education.

Literature Review

Decision-Making Skills in Physics Learning

Current educational policies require a combination of technology, instructional design, and decision-making (Mettas, 2011). The Industry 4.0 era requires graduates with strong decision-making skills (Torres et al., 2023). Decision-making skills are necessary for success in today's professional landscape (Erol et al., 2016). This is reinforced by the opinion of Olmstead et al. (2023), who stated that physics learning is strengthened by knowledge and the choice to study the subject. Physics learning must be enriched with complex ethical decision-making skills to support students who intend to build future careers outside the field. Decision-making skills fall within cognitive development and have become a significant focus in scientific studies. Therefore, physics learning is highly relevant to scientific inquiry, decision-making, and the habit of solving complex problems in physics learning.

Higher education plays a crucial role in preparing students to compete globally. Therefore, higher education curricula need to be designed to integrate decision-making skills into every department within the institution, including physics. As stated in previous studies, scientific decision-making practices are closely related to learning the processes and practices of science (Holmes et al., 2020). For example, laboratory experiments in physics are typically designed to stimulate students to solve real-world problems, select the best solution, determine tools and materials, and design practical procedures. Decision-making skills can be practiced during traditional physics laboratory activities. Generally, students' decisions during practical activities include the equipment used, the amount of data to collect, and how to analyze experimental data. Physics learning encourages students to think critically and make decisions. According to Vygotsky's constructivist theory, students actively construct knowledge through experience during learning activities.

Decision-making style is a learned and habitual response pattern that individuals typically exhibit when facing problems. Decision-making skills are related to students' cognitive styles. Decision-making styles are intuitive and rational (Abubakar et al., 2019). Intuitive decision-making is a right-brain decision-

making style that prioritizes feelings over facts. Intuitive decision-making can be based on experience or previous knowledge (metacognitive). Meanwhile, the rational decision-making process is characterized by identifying problems, generating possible solutions, selecting feasible solutions, and implementing and evaluating the chosen solutions. Rational decision-making is influenced by knowledge management.

The success of physics learning can be measured using assessment instruments. One physics learning instrument is designed to assess students' decision-making skills. This approach suggests that after students have mastered physics theory and engaged in appropriate practice, the results obtained from solving problems should be measured through decision-making assessments. Electricity is a crucial physics topic related to everyday life applications and requires problem-solving. Therefore, the problem-solving process requires complex knowledge and appropriate decision-making skills. This aligns with Jeong et al.'s (2024) opinion that students must be trained to solve complex problems and improve their physics knowledge through learning designs and assessments that measure decision-making skills.

Studies show differences in decision-making skills between males and females (Villanueva-Moya and Expósito, 2021). This suggests that gender stereotype threat can influence the decision-making processes of both genders and has important implications for educational decision-making and gender interventions. This explanation is supported by the fact that men are often more likely to take risks and be selective in achieving their goals through individual decisions. At the same time, women are more conservative (Lozano et al., 2017). Individual decision-making skills are influenced by conceptual mastery, psychological conditions, and gender differences (Sokol et al., 2019; Byrne et al., 2020; Villanueva-Moya and Expósito, 2021).

Rasch Analysis

George Rasch, a Danish mathematician, developed Rasch measurement. Rasch measurement is based on the interaction of items, individuals, and probability estimates. Rasch analysis is used in research to overcome the limitations of classical test theory. In this study, Rasch analysis is used for objective measurement, which includes examining the relationship between individuals and items related to decision-making skills. Previous studies have explored the decision-making skills of physics (Holmes et al., 2020) and chemical engineering students through parametric data analysis (Burkholder et al., 2021). However, after reviewing the existing literature, no publication has adopted Rasch analysis to assess decision-making skills in electrical engineering from the perspective of gender and domicile. Rasch analysis has advantages, including the ability to provide consistent and independent measures for samples and items, ensure unidimensionality, assess model fit, and detect differential item functioning (DIF) based on gender, domicile, and clarity of interpretation (Linacre, 2002). Considering the gap, this study aimed to address three key questions, including,

1. How do the validity and reliability of the electricity decision-making skills test hold up based on Rasch parameters?
2. Is there a DIF in the test based on gender and domicile?
3. What are the observed differences in the decision-making skills of students when categorized by gender and domicile?

Materials and Methods

Design, Participant, and Procedure

The present study adopted a quantitative method, with a sample size of 172 students from state universities. The sample comprised 75 male students (43.6%) and 97 female students (56.4%), all of which were science education students who had completed basic physics courses. Accordingly, the students voluntarily answered the test questions over a 90-minute session using a traditional paper-and-pencil format. Through the test, information regarding the gender and place of residence of the study participants was collected. Table 1 presents the demographic profile of the participants.

Table 1. *Demographic profiles in this study*

Demographic		Frequency	Percentage (%)
Gender	Male	75	43.6
	Female	97	56.4
University type	Public	172	100.0
Study programme	Biology Education	102	59.3
	Science Education	70	40.7
Living place	Urban	64	37.2
	Rural	108	62.8

Instruments

The decision-making skills instrument consists of six essay-based questions, with responses evaluated using a rubric. These questions focused on electrical concepts since it is a topic closely connected to the everyday experiences of students. The data collection included administering the test, which students completed within 90 minutes, and respective responses were subsequently scored using a rubric and converted into a scale ranging from 1 to 3. Electrical circuits are crucial elements of physics and are closely related to students' daily lives. However, students have not yet fully mastered the concept of simple electrical circuits (Burde et al., 2022; Burde and Wilhelm, 2020). Therefore, prospective science teachers must have a solid understanding of electricity. The rationale for selecting electrical circuit problems is to train students' thinking skills to solve electrical problems. Students are trained to make decisions based on the electrical phenomena presented in the problems. Furthermore, the physics curriculum in universities recommends that prospective science teachers be trained in decision-making skills (Montgomery et al., 2024).

Table 2. *Electrical topic test questions based on decision-making skills indicators*

Decision-making Indicator	Item
Analyze the existence of several possible alternative answers along with the risks that may arise (DM1)	You are tasked with creating a simple electrical circuit that requires two resistors connected in series. You have three alternative resistors: R_1 = 10 Ω and R_2 = 30 Ω, R_1 = 20 Ω and R_2 = 30 Ω, or R_1 = 30 Ω and R_2 = 40 Ω. a) Select the correct combination of resistors to produce a total resistance of 50 Ω! b) Provide arguments regarding the possible risks of using each resistor combination.
Evaluating the inherent decision-making process (DM2)	An electrical circuit consists of a 9-volt battery and a 6 Ω resistor. A student measures the current in the circuit as 1.5 A. The student uses Ohm's law to calculate the voltage across the circuit. The student obtains a result of 4.5 volts. Evaluate the student's decision!
Analyze the relationship between problems and existing rules or concepts (DM3)	Anwar was asked to design an electrical circuit with a 12-volt battery, a 6 Ω resistor, and a 3Ω lamp. Anwar wanted to determine the current flowing in the circuit and the power consumed by the lamp. Questions: a) How can one articulate the voltage, resistance, and current relationship? b) What is the calculated current flowing through the circuit? c) How do we determine the power the lamp consumes in the circuit? d) In what ways does Ohm's Law connect to the current and power calculation from this circuit?
Understanding the basis of irrelevant decision-making (DM4)	Agus has an electrical circuit consisting of one battery as a voltage source, two lamps (lamps A and B), and one switch. Only lamp A lights up when the switch is pressed, while lamp B remains off. a) Describe the steps to understand why only lamp A lights up when the switch is pressed! b) Identify irrelevant decisions or assumptions in the circuit analysis!
Integrating related beliefs and values (DM5)	You are designing an electrical circuit consisting of a 12-volt battery, a 4-Ω lamp, and a resistor. There are two resistors to choose from: R_1 = 6 Ω and R_2 = 10 Ω. Determine which resistor you will use in the circuit! Provide arguments based on your beliefs and related values!
Detecting errors in answer construction (DM6)	Anwar has an electrical circuit consisting of a 9-volt battery and two parallel resistors, R_1 = 4 Ω and R_2 = 6 Ω, respectively. Anwar was asked to calculate the total current flowing in the circuit. Anwar's answer, for the total current obtained, is 0.9 A. Anwar explained that the total current in the circuit can be calculated by adding the resistances of R_1 and R_2, then dividing the voltage by the total resistance. Based on Anwar's answer, detect the error in Anwar's answer!

Table 2 presents the framework for the electricity decision-making skills instrument. In line with the study by Bavol'ár and Orosová (2015), the instrument is built upon six indicators of decision-making skills namely analyzing the presence of multiple possible alternative answers along with potential risks (consistency in risk perception), examining the relationship between the problem and established rules or concepts (recognizing norms), identifying errors when formulating answers (resistance to framing), understanding the rationale behind irrelevant decisions (resistance to sunk costs), integrating related beliefs and values, as well as evaluating inherent decision-making process.

Data Analysis

WINSTEPS software version 3.73 (Linacre, 2020) was utilized for Rasch analysis, while SPSS version 22 was adopted to describe the quantitative data from the demographic profiles of the participants. The analysis focused on various aspects such as the validity and reliability of both items and participants, item measures and fit criteria, person fit, Wright map, Differential Item Functioning (DIF) based on gender and domicile, as well as Independent t-tests and one-way ANOVA. During the course of the analysis, several important Rasch indicators were examined, including unidimensionality, item and person separation indices, item and person reliability, as well as infit and outfit MNSQ values, all of which were considered essential for evaluating decision-making skills. Unidimensionality is an important metric that ensures the instrument measures what it is supposed to measure. To meet this criterion, the raw variance must exceed 30%, and the unexplained variance of the first contrast should ideally be less than 15% (Laliyo et al., 2021). For reliability, a Cronbach's Alpha value above 0.60 was considered acceptable (Soeharto et al., 2024; Taber, 2018) and in terms of separation indices, a value of two or more signifies sufficient distinction between the ability of a person and the difficulty level of the items (Linacre, 2020). As stated in a previous study, a higher separation index signifies more precise differentiation (Pilatti et al., 2015). Following separation indices, item, and person validity were assessed using fit criteria, with acceptable ranges for the mean square (MNSQ) values of outfit and infit being between 0.5 and 1.5. Additionally, acceptable ranges for Outfit Z-Standard values were between -2.0 and +2.0, and for Point Measure Correlation (PTMA), between 0.4 and 0.85 (Boone et al., 2014).

Results

Validity

The validity of the decision-making skills instrument, which was determined using item and person parameters generated from the Rasch analysis, is detailed in Table 3. As observed, the outfit and infit MNSQ values for both persons and items showed satisfactory fit validity. The mean outfit MNSQ for persons was 0.87, and the infit MNSQ was 0.79, both within the acceptable range of 0.5 to 1.5, accompanied by a positive Point Measure Correlation (PTMA) value. Similarly, the mean outfit MNSQ for items was 0.87, and the infit MNSQ was 1.01, also meeting the fit validity criteria with a positive PTMA value (Boone et al., 2014). The person separation index obtained was 2.78, and this suggested that the participants could be grouped into more than two distinct (heterogeneous) categories based on the respective abilities of the students. Meanwhile, the obtained item separation index of 5.91 showed that the test items effectively differentiated between the decision-making skills of the students. The construct validity of the instrument was further confirmed through its unidimensionality, with 60.6% of raw variance explained by the measure, showing that the instrument reliably assessed the skills of the observed demographic (Ubaidillah et al., 2022). The unexplained variance was 12.9%, which is below the 15% threshold, further supporting the unidimensionality of the instrument.

Table 3. *The summary statistics based on Rasch's measurement*

	Persons	Item
N	172	6
Mean Measure	2.69	0.0
Max. Measure	7.40	2.16
Min. Measure	-5.21	-2.61
SD	4.36	1.41
SE	0.33	0.63
Mean Outfit MNSQ	0.87	0.87
Mean Infit MNSQ	0.79	1.01
Separation	2.78	5.91
Reliability	0.89	0.97
Cronbach's Alpha	0.85	
Log-Likelihood Chi-squared (χ2)	813.08 (df= 799)	
Probability	0.3569*	
Unidimensionality		
Raw variance explained by Measure	60.6%	
Raw unexplained variance	39.4%	
Unexplained variance 1st Contrast	12.9%	

*Normally distributed

In Table 4, the item measures and fit criteria are presented to confirm the validity of the fit at the item level. The item measure values were observed to be within the range from -2.61 to 2.16 logits. Accordingly, the infit and outfit MNSQ values ranged from 0.80 to 1.33 logits, and from 0.61 to 1.31 logits, respectively. These values fall within the acceptable range of 0.5 to 1.5 for fit validity (Infit-Outfit MNSQ), implying that the items met the criteria for fit validity. It is also important to state that the Z-Standards (ZSTD) outfit values ranged from -1.35 to +1.00, implying the students comprehended all items without any significant misconceptions.

Table 4. *Item measure and fit criteria*

Item Number	Measure	Infit MNSQ	Outfit MNSQ	Outflt ZSTD	PTMA
DM1	-0.12	0.80	0.61	-1.35	0.75
DM2	2.16	1.33	1.31	1.00	0.81
DM3	0.33	0.86	0.66	-1.21	0.82
DM4	0.48	0.97	0.77	-0.76	0.51
DM5	-0.24	0.80	0.62	-1.34	0.76
DM6	-2.61	1.28	1.23	0.69	0.77

Reliability

The reliability of the decision-making skills instrument was determined using Cronbach's alpha value, as shown in Table 3. The item reliability was observed to be exceptionally high at 0.98, and the person reliability was strong, with a value of 0.89. As stated in a previous study, Cronbach's alpha of 0.85 confirms that the decision-making skills instrument is reliable (Taber, 2018). Furthermore, the p-value of 0.3569, which is greater than 0.05, showed that the Rasch model provides a good fit for the data analyzed.

Fit Item Analysis

Figure 1 presents the graph of the Bubble fit item analysis carried out during the course of this study. Based on predefined standards, the larger the circles in the diagram, the greater the margin of error, indicating a challenge in distinguishing the abilities of students. However, the smaller the circle, the smaller the standard error, implying that the item is more effective at differentiating student abilities (see Figure 1). In terms of difficulty, items located higher on the scale were observed to be more challenging, while items DM1, DM3, and DM5 are clustered closely together within the fit region, showing that these items were easier but still corresponded properly with the model. Item DM4 is also in the fit area

but presents a higher level of difficulty compared to DM1, DM3, and DM5. On the other hand, DM6 fell into the underfit region, reflecting that the responses to this item do not correspond with the expectations of the model. Item DM2 is also located in the underfit area, although it is positioned closer to the fit line compared to DM6.

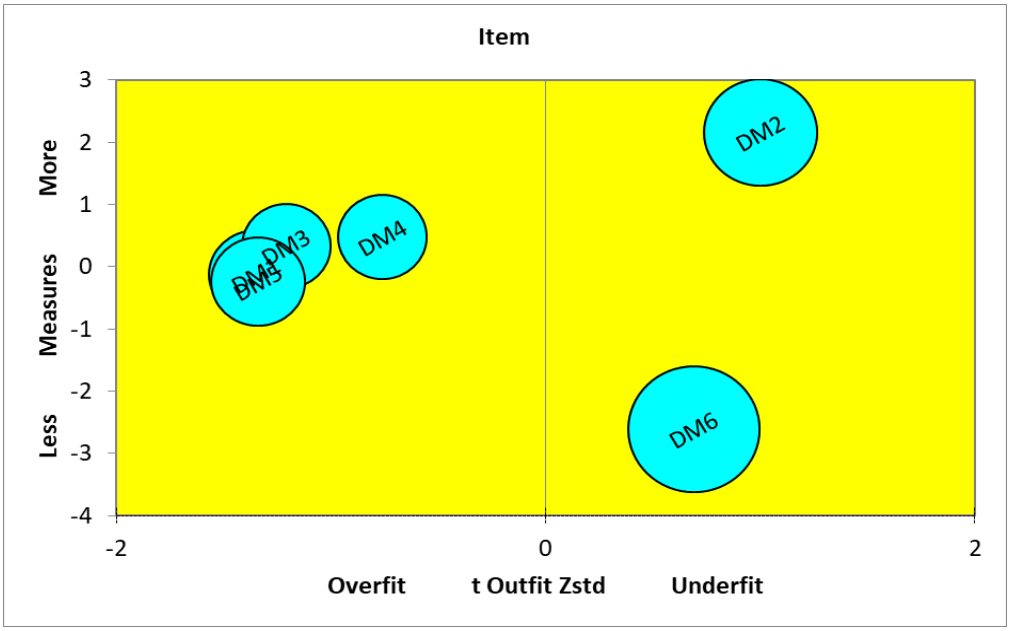

Figure 1. Bubble fit item analysis

Wright Map

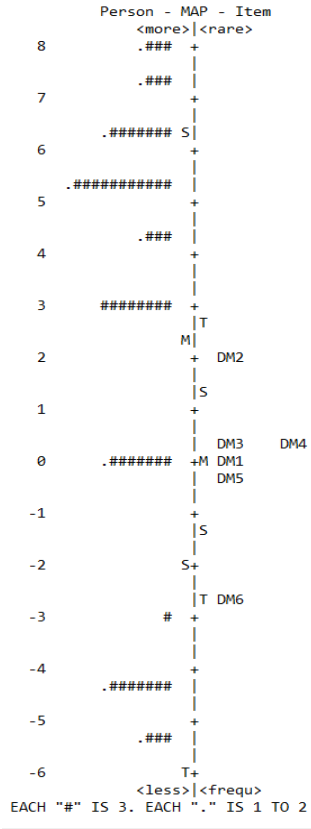

Figure 2. Item-person map

Wright's map was used to gain valuable insights into the difficulty levels of the decision-making skills items considered in this study. The map showed a variety of items, ranging from those that students find challenging to those that are easier to tackle. Typically, items that present significant difficulty can guide teachers in identifying areas where students struggle. This information allows educators to tailor respective instructional strategies and implement targeted interventions to address these weaknesses effectively. By utilizing the insights gained from the Wright map, teachers can enhance respective teaching methods and support students in improving inherent decision-making skills.

From Figure 2, it can be seen that item DM6, which focuses on detecting errors in answers, was perceived as very easy by most students. Dissimilar to this, item DM2, which pertains to self-evaluation, was the most challenging for the students. The participants performed generally well on items DM1, DM3, DM4, and DM5. The Wright map served as a diagnostic tool, emphasizing that students need to enhance performance on item DM2. This information allows teachers to provide targeted remediation for those who struggle with the item. Within this context, educators can emphasize self-evaluation training in decision-making by incorporating case studies and practical laboratory activities to develop students' self-assessment skills.

Differential Item Functioning (DIF) Analysis Based on Gender

DIF analysis was adopted to examine potential gender-based biases that may influence decision-making skills. According to Boone et al. (2014), DIF analysis is effective in identifying participant bias at the item level, allowing for a proper understanding of the manner in which background variables may affect responses to specific items.

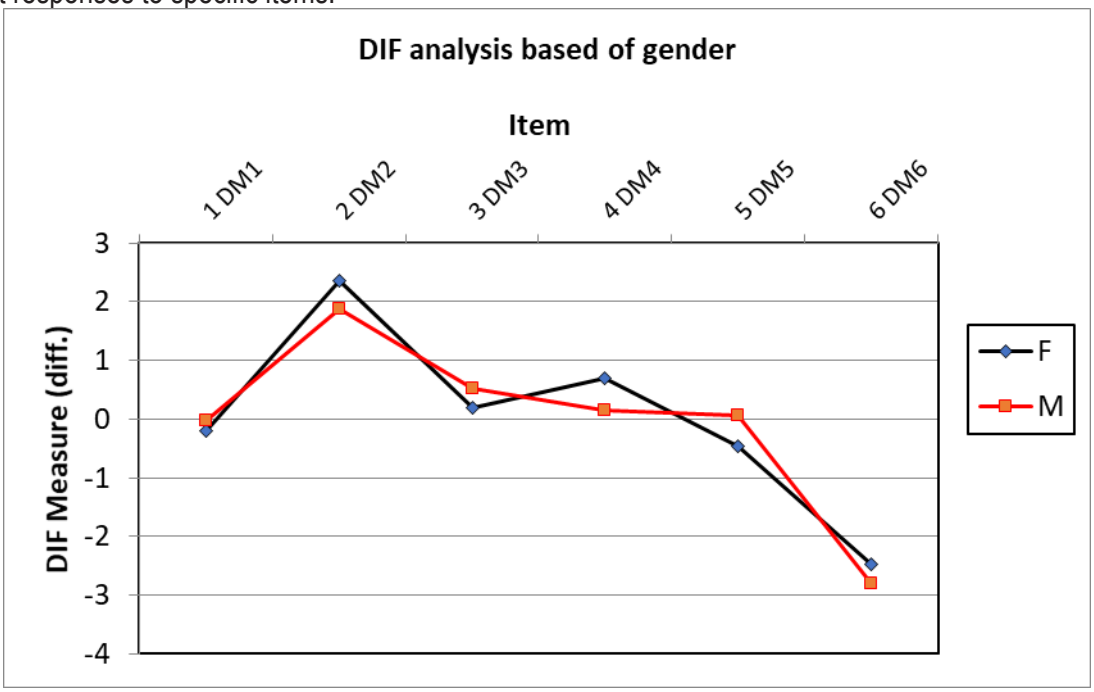

Figure 3. DIF based on gender

Figure 3 presents the graphical representation of the difficulty levels of the items, showing that DM2 was the most challenging, followed by DM4, DM3, DM5, and finally DM1. Based on observation, DM2, DM4, and DM6 posed more challenges for female students compared to the males. However, female students showed stronger performance on items DM1, DM3, and DM5 than male students. Table 5 presents the probability values for all items, which were greater than 0.05. This finding shows that none of the items exhibit gender bias.

Table 5 . *Differential item functioning based on gender*

Item Number	Person Class	Summary Dif Chi-Square	Prob.
DM1	2	0.203	0.652
DM2	2	1.078	0.299
DM3	2	0.708	0.400
DM4	2	1.845	0.174
DM5	2	1.826	0.177
DM6	2	0.326	0.568

Differential Item Functioning (DIF) based on living place

During the course of this study, DIF analysis was instrumental in identifying whether the decision-making skills items had any form of bias related to the geographical location of the observed prospective science teachers. This analytical approach allows for the examination of item bias based on various participant background variables (Boone et al., 2014). Furthermore, according to the established DIF criteria, a probability value greater than 0.05 signifies the absence of significant bias in the items (Soeharto et al., 2024).

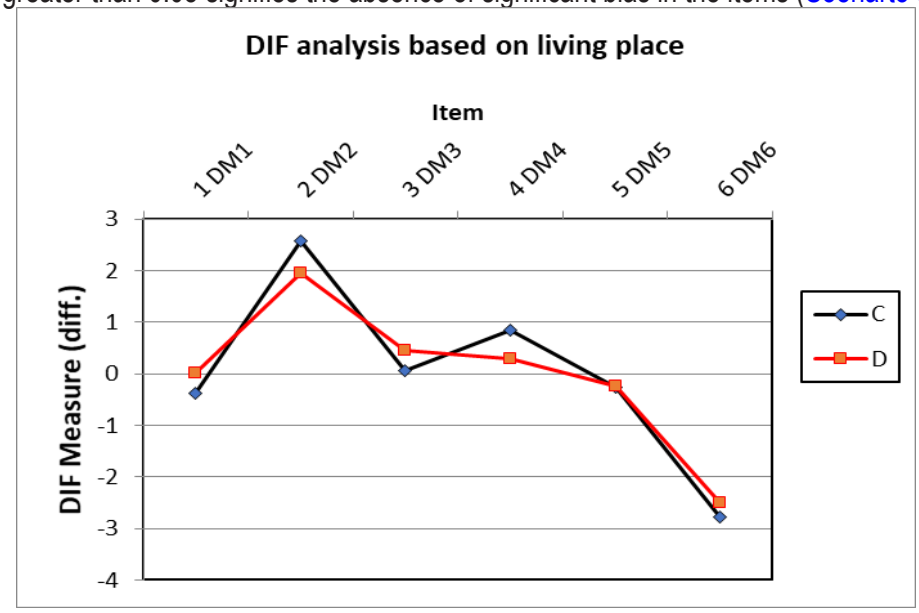

Figure 4. DIF based on domicile

Figure 4 shows that students residing in urban areas (C) performed better on questions DM1, DM3, and DM6 compared to those residing in rural areas (D). However, urban students were observed to face greater challenges with items DM2 and DM4 than those living in the village. Interestingly, for item DM5, students from both areas showed comparable abilities in tackling the question. Table 6 presents the item probability values, which can be used to further assess any potential bias arising from the differences in abilities between urban and rural students.

Table 6. *Differential item functioning based on domicile*

Item Number	Person Class	Summary Dif Chi-Square	Prob.
DM1	2	0.845	0.358
DM2	2	1.295	0.238
DM3	2	0.932	0.335
DM4	2	1.749	0.186
DM5	2	0.005	0.943
DM6	2	0.242	0.623

Table 6 shows that the probability value of the items is greater than 0.05. This implies that all the items did not contain domicile bias.

T-test and ANOVA

Table 7. *The Independent t-test and one-way ANOVA for comparing student decision-making skills between gender and domicile*

Background factor	Group	Mean (SD)	df (df1, df2)	Mean Difference	t-test	F-test	p
Gender	Female	3.30(4.32)	1, 159	1.39	2.09	4.37	0.038
	Male	1.90(4.29)					
Living Place	Urban	3.27(3.92)	1, 148	0.92	1.38	1.90	0.169
	Rural	2.35(4.57)					

The obtained results in their entirety showed that female students possessed superior decision-making skills compared to males, with an average difference of 1.39 logits (see Table 7). The significance value of 0.0385, which is less than 0.05, further confirms a statistically significant difference in decision-making skills between the two genders. This conclusion is further supported by the F-test result of 4.37 and the t-test result of 2.09, reinforcing that the observed difference was not merely due to chance.

In terms of geographic differences, students from urban areas showed better decision-making skills than residents in rural areas, with a difference of 0.92 logits (see Table 7). However, the significance value of 0.169, which exceeds 0.05, implies that this difference was not statistically significant. Considering the implication, no meaningful distinction in decision-making skills was observed based on place of residence.

Discussions

Using the Rasch model as an analytical approach and a form of fair assessment practice. Educators can provide optimal learning services by measuring students' cognitive abilities. Research results show that the Rasch analysis approach measures cognitive abilities (Soeharto and Csapó, 2022). The Rasch model can differentiate the analysis of students' thinking abilities (Chin et al., 2022), distinguish students' interests in learning particle physics (Zoechling et al., 2022), cognitive diagnostics (Chin et al., 2022), critical thinking skills (Kassiavera et al., 2024; Suwita et al., 2023), and analytical thinking in physics learning (Nurussaniah et al., 2025). Therefore, using the Rasch model in measuring cognitive learning outcomes is highly recommended for application in science learning.

The findings of this study show that the physics decision-making skills instrument developed had both validity and reliability. The study emphatically contributes to the measurement of decision-making skills through the Rasch approach and underscores the importance of comprehensive assessments in various contexts. Accordingly, by analyzing item and person characteristics, the exploration provides critical insights that can aid in the development of valid and reliable measurement instruments.

The results of the ANOVA test presented in Table 7 showed that female students had superior decision-making skills compared to male students, with psychological and social factors playing a significant role in explaining this difference. The finding is also supported by previous studies, where it had been suggested that females tend to be more meticulous when making decisions, often considering a multitude of variables and risk factors (Lozano et al., 2017). Research results indicate differences in decision-making skills between males and females (Thi et al., 2022). This finding is supported by studies that show that female students experience greater improvement in decision-making than male students (Khazen et al., 2025). This tendency may be associated with the greater capacity for empathy often found in females, which enhances the decision-making processes of the demographic. Moreover, social and emotional factors, as well as creative and critical thinking, have been observed to be integral to decision-making skills (Abraham et al., 2014). Studies have shown that reasoning and learning environment can influence sustainable decision-making (Khazen et al., 2025; Tutticci and Huss, 2025). Previous investigations have also indicated that during conceptual expansion, males engage areas of the brain associated with semantic cognition, rule learning, and decision-making, while females tend to activate regions related to language processing and social perception. This neurological difference further explains the unique approaches that both genders bring to decision-making.

In accordance with this, the skills of both females and males were observed to be influenced by prevailing gender stereotypes. The obtained results also showed that females were increasingly inter-

ested in studying physics, a field historically associated with males (Eren, 2022). This shift signifies a growing acknowledgment of equality between genders in the realm of science. In line with a previous exploration, the present investigation advocates for gender equality in all educational spaces, emphasizing the need to build scientific identities through intersectional perspectives, visibility of male and female scientists, and gender mainstreaming in scientific production (Buenestado-Fernández et al., 2024). This is particularly important, especially considering the fact that gender bias has been shown to hinder skill development, creating significant gaps across various fields, particularly in STEM disciplines (Barth et al., 2022). However, recent trends suggest that more females are pursuing careers in science, technology, and mathematics (Msambwa et al., 2024). This can be achieved by cultivating a science learning environment that prioritizes gender equality, thereby paving the way for a more inclusive and equitable future in the scientific community.

A study recommends gender mainstreaming in higher education to achieve sustainable development goals (Kataeva et al., 2025). Universities can be influential in promoting gender equality, diversity, and inclusion (Rosa and Clavero, 2022). However, research findings indicate that gender-responsive physics teaching remains limited (Atanasova et al., 2023). This aligns with studies showing that the avoidance of women in physics is a barrier to social progress (Bezen and Derman, 2025). The gender gap is characterized by the continued underrepresentation of women in STEM (Cheryan et al., 2025). Therefore, gender-responsive physics teaching and learning are highly recommended for prospective teachers (Atanasova et al., 2024). Gender-equitable education in higher education for students can be implemented through collaborative project participation, case studies, field trips, and didactic teaching delivery (Condron et al., 2023). Decision-making-based learning design begins with identifying problems, selecting optimal solutions, listing potential possibilities for problem solving, gathering information for problem solving, and analyzing plans (Condron et al., 2023).

When students face decision-making situations, they use intuition, recall previously learned physics concepts, and use patterns to solve problems. Typically, when students encounter complex problems, inherent cognitive processes essential for problem-solving are engaged (Jeong et al., 2024). A good understanding of various concepts enables individuals to analyze situations more effectively, consider a range of alternatives, and evaluate the consequences of the available options. In this regard, further studies are warranted to investigate whether the mastery of physics concepts differs between males and females and how this may significantly impact the physics decision-making skills of each gender. Accordingly, the observations made from the ANOVA test, as presented in Table 7, showed that no significant difference in decision-making skills existed between students residing in urban areas and those in rural areas. These findings are inconsistent with previous investigations, where it has been suggested that socio-demographic factors, particularly place of residence, significantly influence decision-making abilities (Clarke et al., 2024). For instance, Nasmilah et al. (2024) have shown that individuals in rural areas often adhere more closely to cultural norms, and this can impact respective decision-making processes. However, the current study reports that students living in urban and rural environments have similar access to education, resources, and technology, as well as social and cultural conditions.

Education that prioritizes equality between urban and rural students can build a high-quality education system (Guo and Li, 2024). Implementing a school curriculum that is equitable in urban and rural areas has the potential to provide equitable educational opportunities. Teachers can provide equitable physics teaching services to students through experimental learning, inquiry (Gao et al., 2025), group discussions, and decision-making exercises through gamification (Krishnamurthy et al., 2022). Furthermore, teachers with equal competence in urban and rural areas play a role as facilitators who practice decision-making skills. Research findings show no differences in students' decision-making skills between urban and rural areas. This implies that all students, regardless of location, have the potential to develop strong decision-making skills.

Rasch-based decision-making skills instruments can be adopted for biology, chemistry, and environmental courses. Measurement using the Rasch approach not only accurately measures student abilities but also considers psychometric aspects such as validity and reliability. Meanwhile, educational technology is currently developing very rapidly. Decision-making skills instruments can be integrated into digital and classroom-based formative assessments. Studies show that measuring physics thinking skills using the Rasch model approach can be done using a web-based CAT (Zakwandi et al., 2024). Educators can access the assessment results comprehensively and in real time. This allows physics teachers

to follow up on individual abilities quickly and accurately. Therefore, integrating Rasch-based decision-making skills instruments into the classroom can support more adaptive and personalized learning and technological developments.

Conclusions

In conclusion, the results of this study have contributed to the understanding of the interaction of test items and individuals on decision-making skills. The developed electrical decision-making skills test instrument met the requirements of validity and reliability. Therefore, this instrument can be used as an assessment tool. The developed test items were free from bias. Females significantly outperformed males in decision-making. Furthermore, prospective science teachers from urban and rural areas had comparable decision-making skills. This study provides practical recommendations for gender mainstreaming in higher education for stakeholders. Furthermore, teachers design strategies that accommodate gender differences and facilitate an inclusive learning environment. Teachers are advised to implement Rasch-based assessment to provide fair assessments. The Rasch model approach can help teachers identify students' specific needs and enable them to design appropriate remedial and enrichment programs. Future studies should explore the Rasch approach to measure students' decision-making skills more comprehensively, considering variations in decision-making styles, other physics topics, and integrating Rasch with technology.

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Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, B.S., M.U., P.M., W. and H.; Resources, B.S., M.U., P.M., W., and H.; Methodology, M.U., W., and B.S.; Software, M.U., P.M., W., and B.S.; Formal Analysis, B.S., M.U., P.M., W., and H.; Writing – original draft, B.S., M.U., P.M., W., and H.; Writing – review & editing, B.S., M.U., P.M., W., and H. All authors have read and agreed to the published version of the manuscript.

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Can Voice Characteristics Predict the Severity of Depression: A Study on Serbian-Speaking Participants

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Abstract: There is a growing interest in detecting depression through vocal indicators for the purpose of early diagnosis and therapeutic monitoring. Thus, research on voice characteristics in different language areas among individuals with depression may potentially contribute to the standardization of vocal analysis and the development of automatic recognition programs. This study aims to determine whether specific voice characteristics can predict the severity of depression using the Montgomery-Asberg Depression Rating Scale (MADRS) in a sample of Serbian-speaking participants. The analysis included perceptual (GRBAS scale parameters) and acoustic (parameters of frequency variability, intensity variability, and noise and tremor estimation using the MDVP software) voice characteristics in a sample of 100 participants. The sample was divided into two groups: an experimental group of participants diagnosed with depressive disorder (N = 45), including an equal number of participants with mild, moderate, and severe depression (N = 15), and a control group of participants without a depressive disorder diagnosis or depression symptoms (N = 55). The prediction of depression severity based on voice characteristics was conducted using hierarchical regression analysis. The results indicate statistically significant differences in nearly all acoustic and all perceptual voice characteristics among participants with different levels of depression symptoms (MADRS score). Post-hoc analysis revealed no differences in acoustic characteristics between subgroups with different depression severity levels. However, significant differences in perceptual characteristics were found among all subgroups, except between mild and moderate depression. After controlling for gender, age, and smoking status, depression severity demonstrated statistically significant effects on nearly all acoustic and all perceptual voice characteristics. Both perceptual and acoustic voice characteristics can predict the severity of depression. The acoustic parameter of peak amplitude variation (vAm) and the perceptual parameters of hoarseness (G), breathiness (B), asthenia (A), and strain (S) were significant predictors of depression severity. Voice may hold potential as an indicative marker in predicting the severity of depression measured by the MADRS scale. The acoustic parameter related to intensity variation and the perceptual parameters of the GRBAS scale (except voice roughness) appear to be promising voice characteristics in training depression recognition models. Identifying vocal indicators as markers for detecting mental disorders, such as depression, through regression analysis may serve as a foundation for the development of artificial intelligence models for its recognition and may have future clinical relevance.

Keywords: *depression severity, predictors, regression, Serbian language, acoustic analysis, perceptual analysis, biomarker, depression recognition.*

Introduction

Research efforts to detect and monitor mental disorders, such as major depressive disorder (hereafter depression), through objective biomarkers, such as voice, have been growing in recent years. While there is an increasing number of studies exploring vocal characteristics in depression and various high-precision classification models, a voice biomarker for its detection has not been validated yet. Therefore, patient self-reporting remains the only available diagnostic resource (Zhang et al., 2020), alongside sig-

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nificant expertise from professionals (Huang et al., 2024).

In addition to providing greater objectivity and facilitating the diagnostic process, voice-based depression recognition models offer the possibility of collecting data in a relatively easy and non-intrusive manner, while the recording procedure does not require high costs (Huang et al., 2024). However, the models vary in recognition accuracy due to different parameters analyzed in studies, speech tasks, assessment scales, methods of analysis, sample heterogeneity, etc. Common machine-learning approaches for depression recognition include linear regression (Mundt et al., 2012; Silva et al., 2024; Zhao et al., 2022; Yang et al., 2013; Wadle et al., 2024), a support vector machine (Kiss and Jenei, 2020; Liu et al., 2016; Menne et al., 2024; Sahu and Espy-Wilson, 2016; Yalamanchili et al., 2020; Williamson et al., 2018), a Gaussian mixture model (Afshan et al., 2018; Cummins et al., 2015), a combination of methods (Alghowinem et al., 2013; Jiang et al., 2017; Shin et al., 2021) or neural networks (Chlasta et al., 2019; Liang et al., 2024; Rejaibi et al., 2022; Seneviratne and Espy-Wilson, 2021; Wang et al., 2023).

It is observed that the existing literature on this topic is based on studies conducted predominantly in Western and increasingly Eastern countries, which highlights the need for further studies in other language areas to verify the linguistic and cross-cultural consistency of the parameters. Unlike English, where the accented syllable is usually characterized by a higher fundamental frequency (F0), longer duration and greater intensity (stress-accented language), an accented syllable in Serbian is characterized by a change in pitch and duration (pitch-accented language), but not a change in intensity compared to an unaccented syllable or different types of accents (Bjelica, 2012). Also, accent can be on any syllable, except the last one, unlike e.g. Czech and Polish, which, like Serbian, belong to the Slavic languages, and where the accent is always tied to a certain position in the word. In the Serbian language, the tonic accent is phonemic, that is, changes in the pitch of an accented syllable can change the meaning of a word. In contrast to most Slavic languages, Serbian prosodic system is characterized by a combination of tonal and quantitative accent, where tone pitch (ascending/descending) and vowel length (short/long) are phonologically relevant and together participate in distinguishing meaning (Bjelica, 2012). In Serbian, unlike, for example, English, vowels in unstressed syllables remain of the same vocal quality (without reduction) (Nikolić, 2016) which could have impact on differences in prosodic structure. Eastern languages, such as Mandarin, are mostly tonal languages, meaning that each syllable has a specific tone and changing the tone also changes the meaning (lexical function) (Yu et al., 2017). Differences in accentuation between languages can affect speech production and thus vocal biomarkers, such as parameters that express changes in the F0 of the voice and its variability. Therefore, it is also important to take into account the prosodic specificities of a particular language when analyzing voice parameters in the context of emotional states, such as depression. Additionally, research samples often neglect participants with mild depression and include unequal numbers of participants with moderate and severe depression, which limits the prediction. Existing studies in the Serbian-speaking area mostly focus on identifying differences between participants with depression and a control group, while insufficient attention has been given to developing models that enable reliable depression prediction.

Previous paper (Calić et al., 2022a) focused on the discriminative role of voice characteristics in distinguishing between groups with and without depression, while this study explores their predictive role. We included additional voice characteristics, both acoustic and perceptual, in accordance with recommendations from authors in this field to incorporate parameters from different domains. Although research studies most commonly use the Hamilton Depression Rating Scale (HAM-D) and the Beck Depression Inventory (BDI, BDI-II), we used the Montgomery-Asberg Depression Rating Scale (MADRS) due to its good validity and higher discriminative power for moderate and severe depression compared to HAM-D (Müller et al., 2003), as well as its more accurate discrimination of individuals without depression symptoms within primary healthcare compared to BDI-II (Nejati et al., 2020). In addition, the sample included an equal number of participants with different levels of depression severity.

To our knowledge, this study represents the first attempt to identify depression severity predictors based on voice characteristics in the Serbian-speaking area.

Mechanisms Underlying Voice and Depression

Reviewing the literature revealed several potential mechanisms underlying altered voice characteristics in depression. They can be classified into three general groups: neurophysiological/neurobiological, cognitive/psychological, and socio-emotional.

Some authors emphasize neurophysiological mechanisms, such as the impact of psychomotor impairment (slowing of thoughts and limited movements), as a dominant symptom in depression, on speech and voice. Psychomotor slowing is thought to affect laryngeal dynamics and control (Quatieri and Malyska, 2012), and authors most often associate this factor with the voice characteristics that indicate precision in motor control during vocal production, such as voice quality features (Jitter, Shimmer, etc.) (Quatieri and Malyska, 2012; Zhang et al., 2020) and also prosodic (like pitch variability, speech rate and pause time) (Cannizzaro et al., 2004). Changes in muscle tone of the vocal tract as well as the respiratory system, often associated with fatigue in depression (due to changes in the autonomic nervous system), can affect the voice (Zhao et al., 2022). The role of dopamine (DA) deficiency has been emphasized in some studies (Darby et al., 1984), while others point to the contribution of serotonin (5-HT) (Zhao et al., 2022) as a potential neurobiological mechanism underlying altered voice characteristics. These neurotransmitter imbalances are believed to affect neural circuits involving the prefrontal cortex and basal ganglia (Vahid-Ansari and Albert, 2021), which are crucial for motor planning and vocal control, thereby contributing to psychomotor slowing and altered voice production in depression (Yamamoto et al., 2020). In addition to neurophysiological and neurobiological mechanisms, cognitive, psychological and socio-emotional factors also play an important role.

Cognitive deficits, such as impairment of working memory, attention, and executive functions, can affect speech planning and production (Alpert et al., 2001). Cognitive mechanisms are thought to underlie the reduced rate of speech and the greater number of pauses and their longer duration in people with depression. Some authors point out that the total number, duration and variability of pauses in automatic speech tasks (e.g. reading) reflect psychomotor slowing, while cognitive factors are more closely associated with free speech tasks (e.g. word finding during an interview) (Alpert et al., 2001; Mundt et al., 2007). Psychological factors, such as low arousal, lack of motivation, and anhedonia have also been proposed as contributing factors (Almaghrabi et al., 2023).

Ellgring and Scherer (1996) point out that if psychomotor impairment resulting from neurological dysfunction (like neurotransmitter deficiency) were the cause, there would be a general effect of muscle rigidity on speech production, as well as the influence of cognitive deficits, and no, for example, gender differences in voice characteristics among people with depression. They highlight the socio-emotional hypothesis, suggesting that different patterns of speech and voice quality are determined by the type of underlying emotion. Accordingly, if the underlying state is apathy, one would expect lower F0, a slower speech rate, and longer pauses, whereas anxiety is expected to show the opposite pattern. It is assumed that psychomotor slowing is primarily associated with sadness, whereas agitation may reflect a combination of sadness and anxiety (Alpert et al., 2001).

Given the methodological differences across studies, the complex nature of voice, and the heterogeneity of factors associated with depression, the specific underlying mechanism remains an open question. Although the analyses of voice characteristics in depression cannot directly identify the underlying causes, they may enhance understanding of the psychopathological processes involved and inform future research aimed at uncovering these mechanisms.

Voice-Based Depression Recognition

Correlation analyses of voice and depression severity

Numerous research studies confirm the presence of differences in certain voice characteristics, both perceptual (Darby et al., 1984) and more frequently analyzed acoustic ones (Alpert et al., 2001; Jia et al., 2019; Silva et al., 2024; Taguchi et al., 2017; Wang et al., 2019; Zhao et al., 2022), between participants with and without depression. Several studies have also shown that some of these characteristics correlate with the severity of depression (Hönig et al., 2014; Mundt et al., 2012; Yamamoto et al., 2020; Zhao et al., 2022). For example, a Japanese study (Yamamoto et al., 2020) shows that prosodic features

(speech rate, pause period, and response time) significantly correlate with depression severity measured by the Hamilton Depression Rating Scale (HAMD-17). A study conducted in the USA (Cannizzaro et al., 2004) shows that speech rate is significantly negatively correlated with depression severity, but the correlation with percent pause time was not significant. This is contrary to the results of Mundt et al. (2007, 2012) who replicated this finding in a larger sample and demonstrated a significant correlation of both speech rate and percent pause time with depression severity. Sample size and heterogeneity could explain the inconsistency in results. Also, a Chinese study (Zhao et al., 2022) found a positive correlation between spectral parameters, specifically two Mel-frequency cepstral coefficients (MFCC4 and MFCC7), and the Patient Health Questionnaire (PHQ-9), while in another study in Japanese sample (Taguchi et al., 2018) the MFCC coefficients were not significantly associated with severity of depression. Although the speech task (reading paragraphs and numbers) in these studies was the same, it is possible that language differences, sample heterogeneity, different scales for assessing the severity of depression and different voice recording methods may account for differences in results. Some studies (Quatieri and Malyska, 2012) show that voice quality parameters, Jitter and Shimmer, correlate with depression severity (HAMD-17), unlike the F0 parameter. On the other hand, other studies (Mundt et al., 2007; 2012; Hönig et al., 2014) found a significant correlation between F0 and F0 variability with depression severity. It is possible that different languages and speech tasks used in these studies led to inconsistent results.

Predictive analysis of depression severity using voice characteristics

While examining the predictive role of voice in recognizing depression, Hashim et al. (2017) used multiple linear regression and found indications of gender differences. Specifically, acoustic voice characteristics based on reading showed significant predictive value for the HAMD score in both genders, while for the BDI-II, this was only true for men. However, according to the authors, the limiting factor of their study could be that it did not include potential confounding variables, such as smoking history and the voice of professional voice users. By also analyzing voice characteristics based on reading but in a Chinese Mandarin sample, the results of linear regression in the study of Zhao et al. (2022) showed that the MFCC7 parameter predicted the PHQ-9 score, and the MFCC9 parameter predicted the HAMD anxiety score. The results of the multiple linear regression analysis by Silva et al. (2024) indicate that, among the parameters analyzed (mean, mode, and standard deviation of F0, Jitter, Shimmer, glottal to noise excitation ratio, smoothed cepstral peak prominence, and spectral tilt), the Jitter parameter and smoothed cepstral peak prominence serve as predictors of depression measured by the BDI-II. In one longitudinal studies (Wadle et al., 2024), voice characteristics were monitored over a three-week period in participants undergoing sleep deprivation therapy. Results from multilevel linear regression analysis indicated that speech pauses and pitch variability were significant predictors of depression severity (MADRS), whereas speech rate was not a significant predictor. Different types of speech tasks (reading, sustained vowel phonation and continuous speech) within the same vocal analysis, analyzed parameters and depression rating scales may underlie discrepancies in results.

Some authors use a different prediction paradigm, as traditional regression analysis predicts a functional relationship between voice and speech characteristics and depression scores (Cummins et al., 2020). Shin et al. (2021) show that a multilayer processing method, as a machine-learning approach, provides the best recognition results with an accuracy of 65.6%. Also, as one of the scarce studies that includes participants with minor depression, the mentioned research found that this method can differentiate between participants with minor and major depressive disorder. Du et al. (2022) analyzed acoustic voice characteristics (voice quality, prosodic and spectral features) based on reading a text in a smaller sample of participants with depression. Principal component analysis was first applied, followed by a multilayer perceptron to establish and compare a classification model with traditional classifiers. The multilayer perceptron provided the best results with an accuracy of 0.875. In addition to traditional machine learning, there have recently been attempts to detect depression using neural networks. A longitudinal study (Wang et al., 2023) shows that a neural network-based model can predict depression severity based on acoustic voice characteristics, with a correlation coefficient of 0.684. A model based on a convolutional neural network (Chlasta et al., 2019) also showed the ability to recognize depression from speech with an accuracy of 77%. The variability in prediction accuracy across these models can be attributed to differences in sample characteristics, analysis methods, and selected features, and speech tasks.

Research Hypothesis

Although traditional machine learning and neural network models often show a high degree of accuracy in the prediction of depression based on acoustic characteristics, some authors point out that simpler models (like logistic or linear regression) are efficient enough and do not differ significantly from more complex models (like neural networks), provided the data are clear and aligned with the characteristics of what is being examined (Rudin, 2019). We share the view that linear regression retains an important role and enables a clear interpretation of the relationship between predictors and criteria, providing insight into which voice characteristics contribute most to the severity of depression. Our hypothesis is that voice characteristics (both perceptual and acoustic) will have a predictive value in determining the severity of depression. If voice characteristics are found to have potential as an objective biomarker of depression in our sample through regression analysis, this could contribute to the creation of artificial intelligence AI models in the future, allowing for comparison and deepening of this knowledge.

Aim of the Research

Our research aims to determine whether specific voice characteristics, perceptual and acoustic, can predict the severity of depression measured by the MADRS scale in a sample of Serbian speakers.

Materials and Methods

The sample

The study included 100 participants, with the experimental group consisting of 45 participants diagnosed with a depressive disorder and the control group consisting of 55 participants without a depressive disorder. The experimental group included three subgroups based on depression severity: mild, moderate, and severe. Each subgroup consisted of 15 participants. The sample included only participants aged between 18 and 64 years, with no comorbid psychiatric disorders or somatic diseases (which could affect the voice) and professional voice users with fewer than ten years of work experience. The participants were native speakers of Serbian. Since physiological changes associated with aging can affect the vocal cords and voice quality (Petrović-Lazić and Ilić Savić, 2023; Petrović-Lazić et al., 2008), elderly participants were not selected. A psychiatrist made the diagnosis based on an interview and the guidelines provided in the DSM-V (APA, 2013) and additionally applied the MADRS scale to determine the severity of depression. The experimental and control groups were not statistically significantly different in gender ($\chi 2 = 0.756$, $p > 0.05$) or age ($F = 0.080$, $p > 0.05$).

Table 1. *Sample characteristics*

Variable		Experimental group	Control group
Number of participants	N = 100	45	55
Gender	Male	15	23
	Female	30	32
Age (M ± SD)		45.82 ± 12.520	41.29 ± 12.060
Smoking status	Yes	28	14
	No	17	41
Depression severity	Without depression symptoms	0	55
	Mild depression	15	0
	Moderate depression	15	0
	Severe depression	15	0

The participants in the experimental group were selected based on the psychiatrist's recommendation following the diagnostic and research criteria. The participants in the control group were conveniently selected from Kragujevac and its surroundings, matched by gender and age with the experimental group participants. Data on diagnosis, the absence of comorbid psychiatric and somatic conditions, and sociodemo-

graphic data (gender, age, profession, smoking status) were obtained from medical records and interviews.

Procedure and instruments

The study was approved by the Ethics Committee of the University Clinical Center Kragujevac (no. 01/21-422) and was conducted at the Psychiatry Clinic between 2021 and 2023. The research conducted with each participant individually started only after they received a detailed explanation of the purpose and procedure of the study and signed the informed consent for participation in the research.

The recording was done in a room isolated from distractions and noise. A speech therapist conducted the voice recording, while a psychiatrist administered the MADRS scale to obtain data on depression severity.

The severity of depression was assessed using the Montgomery-Asberg Depression Rating Scale (MADRS; Montgomery and Asberg, 1979). The scale was validated for the Serbian-speaking population (Mihajlović et al., 2021) and showed high internal reliability (α = 0.84). It includes ten items with a seven-point Likert-type scale (0 - no symptoms; 6 - severely expressed symptoms). The items primarily assess the main symptoms of depression (sadness, tension, concentration, fatigue, loss of interest, pessimistic thoughts), as well as somatic symptoms (appetite, sleep). The psychiatrist rates one item, while the participants self-assess the remaining nine. In our study, the Cronbach's alpha value indicates that the scale is highly reliable (α = 0.97).

The Multidimensional Voice Program (MDVP) by Kay Elemetrics, model 4300, was used to analyze acoustic voice characteristics. This software allows for the acoustic analysis of 33 parameters in numerical and graphical form (Petrović-Lazić, 2021). The participants had a task to sustain the vowel /a/ for approximately three seconds. A Sony ECM-T150 microphone was used for recording, positioned about 5 cm from the participant's mouth.

We analyzed 15 acoustic parameters in the domains of frequency variability (F0, Fhi, Flo, vF0, PFR, STD, Jitt, PPQ), intensity variability (ShdB, Shim, vAm, APQ), and noise and tremor estimation (NHR, VTI, SPI). The voice characteristics were chosen based on their frequent use in examining voice acoustics in depression and, generally, in voice pathology.

Perceptual voice characteristics were analyzed using the GRBAS scale (Isshiki et al., 1969). The participants had a task to read a phonetically balanced text. Each parameter of the GRBAS scale – G (grade) for overall hoarseness, R (roughness) for vocal roughness, B (breathiness) for vocal breathiness, A (asthenia) for vocal weakness, and S (strain) for vocal tension – was independently assessed by three voice pathologists using a four-point rating scale (0 = normal; 1 = mild/low degree; 2 = moderate/moderate degree; 3 = severe/high degree), after which the average score was calculated.

Table 2. *Kappa coefficients of inter-rater agreement for perceptual characteristics of voice between pairs of raters*

		1 vs 2	1 vs 3	2 vs 3
G	Kappa	0.835	0.888	0.831
	p	**0.000**	**0.000**	**0.000**
R	Kappa	0.615	0.639	0.852
	p	**0.000**	**0.000**	**0.000**
B	Kappa	0.708	0.752	0.693
	p	**0.000**	**0.000**	**0.000**
A	Kappa	0.785	0.803	0.718
	p	**0.000**	**0.000**	**0.000**
S	Kappa	0.680	0.747	0.848
	p	**0.000**	**0.000**	**0.000**

Kappa values indicated substantial agreement between raters across perceptual voice characteristics, with the strongest agreement for parameter G (almost perfect). All values were statistically significant (p = 0.000).

While some researchers argue that sustained vowel phonation is a more precise measure for objective voice analysis (Gerratt et al., 2016; Nguyen et al., 2024), others suggest that continuous speech is more suitable for the perceptual identification of hoarseness due to the greater number of vocal fold vibrations and increased vocal strain (Stráník, 2014), which justifies our choice of speech tasks within both vocal analyses.

The effectiveness of the MDVP software and the GRBAS scale for assessing voice quality was confirmed by research conducted in the Serbian-speaking area (e.g. Arsenić et al., 2021; Calić et al., 2022b; Petrović-Lazić et al., 2016; Šehović et al., 2017).

Table 3. *Analyzed voice characteristics*

Domains of voice characteristics	Voice characteristics labels	Explanation of labels
Parameters of frequency variability	F0	average fundamental frequency
	Fhi	highest fundamental frequency
	Flo	lowest fundamental frequency
	vF0	coefficient of fundamental frequency variation
	PFR	phonatory fundamental frequency range
	STD	standard deviation of the fundamental frequency
	Jitt	Jitter percent
	PPQ	pitch perturbation quotient
Parameters of intensity variability	ShdB	Shimmer in dB
	Shim	Shimmer percent
	vAm	peak amplitude variation
	APQ	amplitude perturbation quotient
Parameters of noise and tremor estimation	NHR	noise-to-harmonic ratio
	VTI	voice turbulence index
	SPI	soft phonation index
Perceptual parameters	G	overall grade of hoarseness
	R	roughness in voice
	B	breathiness in voice
	A	asthenia in voice
	S	strain in voice

Statistical data analysis

The analyses included both descriptive and analytical statistical measures. The following descriptive measures were presented: minimum, maximum, arithmetic mean, standard deviation, median, and interquartile range. Based on the results of the Kolmogorov-Smirnov test, which indicated that the distribution of the obtained measures significantly deviated from a normal distribution, nonparametric statistical methods were used. The Kruskal-Wallis test was applied to examine differences in numerical variables between groups, while Dunn-Bonferroni post hoc analyses were used to determine differences between specific subgroup pairs. MANCOVA was additionally performed to assess whether subgroups of different depression severity levels differed in voice characteristics, after adjusting for the effects of gender, age and smoking status as covariates. Hierarchical regression analysis was conducted to assess the predictive role of independent variables on the dependent variable. The level of statistical significance was set at $p \leq 0.05$.

The statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), version 26 (2019).

Results

Descriptive measures and testing differences in voice characteristics

Table 4 presents the descriptive measures for acoustic voice characteristics in participants with different levels of depression symptoms and determines the significance of differences among them.

Table 4. *Descriptive measures for acoustic voice characteristics in participants with different levels of depression symptoms and testing differences*

	Groups	N	Min	Max	M(SD)	95% CI	Mdn (IQR)	Kruskal-Wallis test
Fo	none	55	84.962	269.600	171.356(51.017)	157.564-185.148	178.709(83.514)	KW = 5.163 df= 3 p = 0.160
	mild	15	100.311	210.129	161.282(38.841)	139.772-182.791	175.200(68.871)	
	moderate	15	107.405	213.997	146.698(36.774)	126.334-167.063	145.510(57.930)	
	severe	15	102.352	214.800	144.945(36.488)	124.739-165.151	137.519(45.557)	
Fhi	none	55	99.644	314.954	186.281(58.509)	170.464-202.099	195.111(97.662)	KW = 0.800 df = 3 p = 0.849
	mild	15	110.860	238.701	181.149(42.640)	157.536-204.763	193.614(82.295)	
	moderate	15	116.727	245.661	179.665(46.745)	153.779-205.552	183.276(95.493)	
	severe	15	111.579	253.318	174.079(46.312)	148.433-199.726	172.195(71.826)	
Flo	none	55	77.257	251.699	155.194(46.442)	142.639-167.749	162.680(73.111)	KW =11.408 df = 3 **p = 0.010**
	mild	15	87.722	190.773	142.106(36.012)	122.163-162.049	158.641(69.132)	
	moderate	15	74.000	180.463	125.373(33.252)	106.958-143.787	111.216(59.861)	
	severe	15	68.657	200.858	118.990(35.824)	99.151-138.828	112.147(43.755)	
STD	none	55	.893	13.607	2.951(2.038)	2.400-3.502	2.484(1.769)	KW = 21.245 df = 3 **p = 0.000**
	mild	15	1.498	6.660	4.227(1.494)	3.400-5.054	3.952(2.563)	
	moderate	15	1.189	16.251	5.969(3.887)	3.817-8.122	6.143(4.521)	
	severe	15	1.528	40.985	9.972(11.951)	3.354-16.590	5.528(5.350)	
PFR	none	55	1.000	11.000	4.091(2.263)	3.479-4.703	3.000(4.000)	KW = 21.402 df = 3 **p = 0.000**
	mild	15	3.000	10.000	5.133(2.200)	3.915-6.351	4.000(4.000)	
	moderate	15	3.000	16.000	7.800(4.491)	5.313-10.287	7.000(9.000)	
	severe	15	3.000	18.000	8.533(4.984)	5.773-11.293	7.000(6.000)	
vF0	none	55	.636	6.426	1.723(0.933)	1.470-1.975	1.513(1.009)	KW = 32.671 df = 3 **p = 0.000**
	mild	15	1.207	5.380	2.718(1.095)	2.112-3.325	2.710(1.746)	
	moderate	15	1.060	15.130	4.199(3.428)	2.300-6.097	3.536(2.010)	
	severe	15	1.449	25.212	6.167(6.930)	2.329-10.004	3.673(3.166)	
Jitt	none	55	.266	1.931	0.626(0.346)	0.533-0.720	0.557(0.346)	KW = 39.779 df = 3 **p = 0.000**
	mild	15	0.389	3.777	1.400(0.889)	0.907-1.892	1.391(0.982)	
	moderate	15	0.535	5.172	1.573(1.257)	0.877-2.269	1.165(0.862)	
	severe	15	0.373	4.223	2.210(1.310)	1.484-2.935	2.012(2.259)	
ShdB	none	55	0.106	0.897	0.313(0.159)	0.270-0.356	0.262(0.163)	KW = 36.809 df = 23 **p = 0.000**
	mild	15	0.220	0.951	0.449(0.199)	0.339-0.559	0.370(0.205)	
	moderate	15	0.286	1.395	0.632(0.315)	0.458-0.807	0.509(0.236)	
	severe	15	0.266	1.144	0.616(0.236)	0.485-0.746	0.597(0.362)	
Shim	none	55	1.225	9.720	3.488(1.753)	3.015-3.962	2.933(1.879)	KW = 36.971 df = 3 **p = 0.000**
	mild	15	2.500	10.650	5.042(2.120)	3.868-6.216	4.288(2.386)	
	moderate	15	3.303	12.408	6.662(2.902)	5.054-8.269	5.449(2.745)	
	severe	15	2.963	11.369	6.735(2.398)	5.407-8.062	6.795(4.150)	

	Groups	N	Min	Max	M(SD)	95% CI	Mdn (IQR)	Kruskal-Wallis test
APQ	none	55	.878	6.803	2.724(1.224)	2.393-3.054	2.437(1.298)	KW = 39.012 df = 3 **p = 0.000**
	mild	15	2.001	7.207	3.762(1.429)	2.970-4.553	3.614(1.424)	
	moderate	15	2,754	9.337	4.951(1.925)	3.885-6.017	4.376(1.651)	
	severe	15	2.924	7.744	4.915(1.461)	4.106-5.724	5.006(2.875)	
PPQ	none	55	0.150	1.112	0.354(0.191)	0.303-0.406	0.294(0.211)	KW = 41.397 df = 3 **p = 0.000**
	mild	15	0.240	2.506	0.834(0.590)	0.508-1.161	0.739(0.581)	
	moderate	15	0.303	3.164	0.904(0.734)	0.498-1.311	0.673(0.552)	
	severe	15	0.214	2.539	1.328(0.817)	0.876-1.781	1.188(1.553)	
vAm	none	55	4.377	26.488	10.191(5.328)	8.750-11.631	8.629(5.410)	KW = 41.945 df = 3 **p = 0.000**
	mild	15	6.127	36.293	19.878(8.724)	15.046-24.709	18.997(15.316)	
	moderate	15	7.717	43.602	21.397(8.825)	16.510-26.284	21.026(7.901)	
	severe	15	11.915	42.912	21.160(8.523)	16.441-25.880	19.176(13.713)	
NHR	none	55	0.106	0.250	0.136(0.023)	0.130-0.143	0.136(0.025)	KW = 23.727 df = 3 **p = 0.000**
	mild	15	0.114	0.199	0.150(0.025)	0.137-0.164	0.143(0.022)	
	moderate	15	0.124	0.274	0.176(0.038)	0.155-0.197	0.165(0.033)	
	severe	15	0.118	0.270	0.173(0.050)	0.146-0.201	0.155(0.077)	
VTI	none	55	0.014	0.106	0.055(0.017)	0.051-0.060	0.054(0.025)	KW = 1.987 df = 3 p = 0.575
	mild	15	0.024	0.088	0.056(0.017)	0.047-0.066	0.055(0.024)	
	moderate	15	0.026	0.095	0.059(0.019)	0.048-0.069	0.060(0.032)	
	severe	15	0.021	0.108	0.063(0.022)	0.051-0.075	0.067(0.034)	
SPI	none	55	1.697	32.791	6.593(4.481)	5.381-7.804	6.006(3.365)	KW = 19.451 df = 3 **p = 0.000**
	mild	15	2.882	18.861	9.162(5.184)	6.291-12.033	7.473(10.353)	
	moderate	15	4.331	19.894	9.206(4.553)	6.685-11.727	8.305(6.033)	
	severe	15	4.456	16.019	10.773(3.413)	8.883-12.663	10.242(6.383)	

Notes: N = number of participants; Min = minimum; Max = maximum; M = arithmetic mean; SD = standard deviation; 95% CI = 95% confidence interval (lower and upper bound); Mdn = median; IQR = interquartile range; KW = Kruskal-Wallis test; df = degrees of freedom; p = statistical significance

The results of the Kruskal-Wallis test indicate statistically significant differences among participants with different levels of depression symptoms (none, mild, moderate, severe) for all analyzed acoustic voice characteristics ($p \leq 0.01$) except for the average fundamental frequency (F0), the highest fundamental frequency (Fhi), and the voice turbulence index (VTI) ($p > 0.05$).

Dunn-Bonferroni analyses were applied to more precisely determine which pairs of subgroups, according to depression severity, show differences in acoustic voice characteristics (Table 5).

Table 5. *Results of the Kruskal-Wallis test with Dunn-Bonferroni analyses examining the differences between pairs of subgroups according to depression severity with regard to acoustic voice characteristics*

			Test statistic	Std.Error	Std. Test Statistic	p	Adj. p
Flo	severe	moderate	3.533	10.593	0.334	0.739	1.000
	severe	mild	15.733	10.593	1.485	0.137	0.825
	severe	none	23.897	8.451	2.828	**0.005**	0.028
	moderate	mild	12.200	10.593	1.152	0.249	1.000
	moderate	none	20.364	8.451	2.410	**0.016**	0.096
	mild	none	8.164	8.451	0.966	0.334	1.000
STD	none	mild	-21.970	8.451	-2.600	**0.009**	0.056
	none	moderate	-28.636	8.451	-3.389	**0.001**	0.004
	none	severe	-28.970	8.451	-3.428	**0.001**	0.004
	mild	moderate	-6.667	10.593	-0.629	0.529	1.000
	mild	severe	-7.000	10.593	-0.661	0.509	1.000
	moderate	severe	-.333	10.593	-0.031	0.975	1.000
PFR	none	mild	-14.721	8.359	-1.761	0.078	0.469
	none	moderate	-27.688	8.359	-3.312	**0.001**	0.006
	none	severe	-31.955	8.359	-3.823	**0.000**	0.001
	mild	moderate	-12.967	10.478	-1.237	0.216	1.000
	mild	severe	-17.233	10.478	-1.645	0.100	0.600
	moderate	severe	-4.267	10.478	-0.407	0.684	1.000
vF0	none	mild	-26.018	8.451	-3.079	**0.002**	0.012
	none	moderate	-35.352	8.451	-4.183	**0.000**	0.000
	none	severe	-36.752	8.451	-4.349	**0.000**	0.000
	mild	moderate	-9.333	10.593	-0.881	0.378	1.000
	mild	severe	-10.733	10.593	-1.013	0.311	1.000
	moderate	severe	-1.400	10.593	-0.132	0.895	1.000
Jitt	none	mild	-30.855	8.451	-3.651	**0.000**	0.002
	none	moderate	-34.421	8.451	-4.073	**0.000**	0.000
	none	severe	-43.088	8.451	-5.099	**0.000**	0.000
	mild	moderate	-3.567	10.593	-0.337	0.736	1.000
	mild	severe	-12.233	10.593	-1.155	0.248	1.000
	moderate	severe	-8.667	10.593	-0.818	0.413	1.000
ShdB	none	mild	-22.539	8.451	-2.667	**0.008**	0.046
	none	moderate	-38.273	8.451	-4.529	**0.000**	0.000
	none	severe	-40.339	8.451	-4.774	**0.000**	0.000
	mild	moderate	-15.733	10.593	-1.485	0.137	0.825
	mild	severe	-17.800	10.593	-1.680	0.093	0.557
	moderate	severe	-2.067	10.593	-0.195	0.845	1.000
Shim	none	mild	-23.533	8.451	-2.785	**0.005**	0.032
	none	moderate	-38.067	8.451	-4.505	**0.000**	0.000
	none	severe	-40.400	8.451	-4.781	**0.000**	0.000
	mild	moderate	-14.533	10.593	-1.372	0.170	1.000
	mild	severe	-16.867	10.593	-1.592	0.111	0.668
	moderate	severe	-2.333	10.593	-0.220	0.826	1.000

			Test statistic	Std.Error	Std. Test Statistic	p	Adj. p
APQ	none	mild	-22.294	8.451	-2.638	**0.008**	0.050
	none	moderate	-39.961	8.451	-4.729	**0.000**	0.000
	none	severe	-41.261	8.451	-4.883	**0.000**	0.000
	mild	moderate	-17.667	10.593	-1.668	0.095	0.572
	mild	severe	-18.967	10.593	-1.790	0.073	0.440
	moderate	severe	-1.300	10.593	-0.123	0.902	1.000
PPQ	none	mild	-31.091	8.451	-3.679	**0.000**	0.001
	none	moderate	-35.891	8.451	-4.247	**0.000**	0.000
	none	severe	-43.624	8.451	-5.162	**0.000**	0.000
	mild	moderate	-4.800	10.593	-0.453	0.650	1.000
	mild	severe	-12.533	10.593	-1.183	0.237	1.000
	moderate	severe	-7.733	10.593	-0.730	0.465	1.000
vAm	none	mild	-34.370	8.451	-4.067	**0.000**	0.000
	none	severe	-38.836	8.451	-4.596	**0.000**	0.000
	none	moderate	-39.703	8.451	-4.698	**0.000**	0.000
	mild	severe	-4.467	10.593	-0.422	0.673	1.000
	mild	moderate	-5.333	10.593	-0.503	0.615	1.000
	severe	moderate	.867	10.593	0.082	0.935	1.000
NHR	none	mild	-17.476	8.448	-2.069	**0.039**	0.232
	none	severe	-25.776	8.448	-3.051	**0.002**	0.014
	none	moderate	-36.142	8.448	-4.278	**0.000**	0.000
	mild	severe	-8.300	10.590	-0.784	0.433	1.000
	mild	moderate	-18.667	10.590	-1.763	0.078	0.468
	severe	moderate	10.367	10.590	0.979	0.328	1.000
SPI	none	mild	-17.485	8.451	-2.069	**0.039**	0.231
	none	moderate	-20.085	8.451	-2.377	**0.017**	0.105
	none	severe	-33.885	8.451	-4.010	**0.000**	0.000
	mild	moderate	-2.600	10.593	-0.245	0.806	1.000
	mild	severe	-16.400	10.593	-1.548	0.122	0.730
	moderate	severe	-13.800	10.593	-1.303	0.193	1.000

Notes: p = statistical significance; Adj. p = adjusted statistical significance

The results indicate significant differences between participants without depression and those with depression (mild, moderate, severe) for all acoustic voice characteristics ($p < 0.05$) except for the lowest fundamental frequency (Flo) and the fundamental frequency range (PFR) ($p > 0.05$) between participants without depression and those with mild depression, while no significant differences ($p > 0.05$) were observed between subgroups of participants with mild, moderate, and severe depression.

Table 6. *Descriptive measures for perceptual voice characteristics in participants with different levels of depression symptoms and testing differences*

	Groups	N	Min	Max	M(SD)	95% CI	Mdn (IQR)	Kruskal-Wallis test
G	none	55	0.000	1.000	0.055(0.229)	-0.007- 0.117	0.000(0.000)	KW = 32.731 df = 3 **p = 0.000**
	mild	15	0.000	1.000	0.156(0.330)	-0.027- 0.338	0.000(0.000)	
	moderate	15	0.000	1.667	0.511(0.589)	0.185- 0.837	0.000(1.000)	
	severe	15	0.000	2.333	0.911(0.791)	0.473- 1.349	1.000(1.667)	
R	none	55	0.000	1.000	0.103(0.300)	0.022- 0.184	0.000(0.000)	KW = 22.003 df = 3 **p = 0.000**
	mild	15	0.000	0.667	0.067(0.187)	-0.037- 0.170	0.000(0.000)	
	moderate	15	0.000	1.667	0.267(0.507)	-0.014- 0.547	0.000(0.667)	
	severe	15	0.000	2.000	0.667(0.678)	0.291- 1.042	0.667(1.000)	
B	none	55	0.000	1.000	0.097(0.246)	0.031- 0.163	0.000(0.000)	KW = 39.004 df = 3 **p = 0.000**
	mild	15	0.000	1.667	0.533(0.615)	0.193- 0.874	0.333(1.000)	
	moderate	15	0.000	1.333	0.378(0.517)	0.091- 0.664	0.000(1.000)	
	severe	15	0.000	2.000	1.111(0.600)	0.779- 1.443	1.000(1.000)	
A	none	55	0.000	1.000	0.079(0.248)	0.012-0.146	0.000(0.000)	KW = 33.526 df = 3 **p = 0.000**
	mild	15	0.000	1.000	0.267(0.402)	0.044- 0.489	0.000(0.667)	
	moderate	15	0.000	1.333	0.511(0.486)	0.242- 0.780	0.667(1.000)	
	severe	15	0.000	2.000	0.889(0.626)	0.542- 1.235	1.000(1.333)	
S	none	55	0.000	1.000	0.091(0.276)	0.016- 0.165	0.000(0.000)	KW = 30.947 df = 3 **p = 0.000**
	mild	15	0.000	1.000	0.244(0.320)	0.067- 0.422	0.000(0.333)	
	moderate	15	0.000	1.000	0.467(0.433)	0.227- 0.706	0.667(1.000)	
	severe	15	0.000	1.000	0.711(0.452)	0.461- 0.961	1.000(1.000)	

Notes: N = number of participants; Min = minimum; Max = maximum; M = arithmetic mean; SD = standard deviation; 95% CI = 95% confidence interval (lower and upper bound); Mdn = median; IQR = interquartile range; KW = Kruskal-Wallis test; df = degrees of freedom; p = statistical significance

The results of the Kruskal-Wallis test show statistically significant differences between participants with different levels of depression symptoms for all analyzed perceptual voice characteristics ($p < 0.001$). In addition, Dunn-Bonferroni analyses were conducted to more precisely determine which pairs of subgroups, according to depression severity, show differences in perceptual voice characteristics (Table 7).

Table 7. *Results of the Kruskal-Wallis test with Dunn-Bonferroni analyses examining the differences between pairs of subgroups according to the severity of depression with regard to perceptual voice characteristics*

			Test statistic	Std.Error	Std. Test Statistic	p	Adj. p
G	none	mild	-5.921	6.214	-0.953	0.341	1.000
	none	moderate	-20.621	6.214	-3.318	**0.001**	0.005
	none	severe	-32.488	6.214	-5.228	**0.000**	0.000
	mild	moderate	-14.700	7.790	-1.887	0.059	0.355
	mild	severe	-26.567	7.790	-3.410	**0.001**	0.004
	moderate	severe	-11.867	7.790	-1.523	0.128	0.766
R	none	mild	-.064	6.119	-0.010	0.992	1.000
	none	moderate	-7.797	6.119	-1.274	0.203	1.000
	none	severe	-27.897	6.119	-4.559	**0.000**	0.000
	mild	moderate	-7.733	7.670	-1.008	0.313	1.000
	mild	severe	-27.833	7.670	-3.629	**0.000**	0.002
	moderate	severe	-20.100	7.670	-2.621	**0.009**	0.053

			Test statistic	Std.Error	Std. Test Statistic	p	Adj. p
B	none	moderate	-13.803	7.299	-1.891	0.059	0.352
	none	mild	-20.303	7.299	-2.782	**0.005**	0.032
	none	severe	-44.136	7.299	-6.047	**0.000**	0.000
	moderate	mild	6.500	9.149	0.710	0.477	1.000
	moderate	severe	-30.333	9.149	-3.315	**0.001**	0.005
	mild	severe	-23.833	9.149	-2.605	**0.009**	0.055
A	none	mild	-10.282	6.902	-1.490	0.136	0.818
	none	moderate	-23.815	6.902	-3.450	**0.001**	0.003
	none	severe	-36.448	6.902	-5.281	**0.000**	0.000
	mild	moderate	-13.533	8.652	-1.564	0.118	0.707
	mild	severe	-26.167	8.652	-3.024	**0.002**	0.015
	moderate	severe	-12.633	8.652	-1.460	0.144	0.866
S	none	mild	-13.733	7.028	-1.954	0.051	0.304
	none	moderate	-23.633	7.028	-3.363	**0.001**	0.005
	none	severe	-35.300	7.028	-5.022	**0.000**	0.000
	mild	moderate	-9.900	8.811	-1.124	0.261	1.000
	mild	severe	-21.567	8.811	-2.448	**0.014**	0.086
	moderate	severe	-11.667	8.811	-1.324	0.185	1.000

Notes: p = statistical significance; Adj. p = adjusted statistical significance

The results indicate statistically significant differences between participants without depression and participants with depression for all perceptual voice characteristics ($p < 0.01$) except for hoarseness (G), roughness (R), asthenia (A), and strain (S) ($p > 0.05$) between participants without depression and those with mild depression, as well as roughness (R) and breathiness (B) ($p > 0.05$) between participants without depression and those with moderate depression. Significant differences for all parameters ($p < 0.05$) were found between participants with mild and severe depression, while for R and B parameters ($p < 0.01$), differences were determined between participants with moderate and severe depression. There were no significant differences between participants with mild and moderate depression in any perceptual parameters ($p > 0.05$).

MANCOVA was performed to assess whether subgroups of different depression severity levels differed in voice characteristics, after adjusting for the effects of gender, age and smoking status as covariates (Table 8).

Table 8. *Multivariate effects of gender, age, smoking status and depression severity on acoustic and perceptual voice characteristics*

Acoustic characteristics	Wilks' Lambda	F	df1	df2	p	η^2
gender	0.257	15.25	15	79	**0.000**	0.743
age	0.686	2.41	15	79	**0.006**	0.314
smoking status	0.850	0.93	15	79	0.539	0.150
depression severity	0.338	2.31	45	235.5	**0.000**	0.303
Perceptual characteristics						
gender	0.991	0.163	5	89	0.976	0.009
age	0.813	4.102	5	89	**0.002**	0.187
smoking status	0.935	1.235	5	89	0.300	0.065
depression severity	0.329	8.123	15	246.1	**0.000**	0.309

Notes: df1, df2 = degrees of freedom; p = statistical significance; η^2 = Partial Eta Squared

The results of MANCOVA test show that gender has a statistically significant effect on the overall acoustic characteristics of the voice ($p < 0.001$) with a very large effect size ($\eta^2 = 0.743$). Age also has a

statistically significant, but moderate effect ($p < 0.01$; $\eta^2 = 0.314$), while smoking status has no statistically significant effect ($p > 0.05$). Depression severity has a statistically significant effect ($p < 0.001$), with a moderate effect size ($\eta^2 = 0.303$).

Regarding the perceptual voice characteristics, the MANCOVA test indicates that gender and smoking status have no statistically significant effect ($p > 0.05$). Age has a statistically significant but small effect ($p < 0.01$; $\eta^2 = 0.187$), while depression severity shows a statistically significant effect ($p < 0.001$), with a moderate effect size ($\eta^2 = 0.309$).

Table 9. *Univariate effects of gender, age, smoking status and depression severity on acoustic and perceptual voice characteristics*

Voice characteristics	gender				age				smoking status				depression severity			
	F	df	p	η²	F	df	p	η²	F	df	p	η²	F	df	p	η²
F0	177.040	1	**0.000**	0.656	2.180	1	0.143	0.023	4.316	1	**0.041**	0.044	4.326	3	**0.007**	0.122
Fhi	140.729	1	**0.000**	0.602	0.331	1	0.566	0.004	3.398	1	0.068	0.035	0.859	3	0.465	0.027
Flo	90.433	1	**0.000**	0.493	2.268	1	0.135	0.024	5.815	1	**0.018**	0.059	4.982	3	**0.003**	0.138
STD	10.207	1	**0.002**	0.099	2.848	1	0.095	0.030	1.229	1	0.271	0.013	7.402	3	**0.000**	0.193
PFR	6.952	1	**0.010**	0.070	0.290	1	0.592	0.003	1.062	1	0.306	0.011	9.473	3	**0.000**	0.234
vFo	2.402	1	0.125	0.025	4.337	1	**0.040**	0.045	3.194	1	0.077	0.033	7.145	3	**0.000**	0.187
Jitt	0.802	1	0.373	0.009	3.179	1	0.078	0.033	0.063	1	0.803	0.001	14.383	3	**0.000**	0.317
ShdB	0.433	1	0.512	0.005	1.444	1	0.233	0.015	0.040	1	0.842	0.000	11.937	3	**0.000**	0.278
Shim	1.129	1	0.291	0.012	1.684	1	0.198	0.018	0.010	1	0.920	0.000	12.288	3	**0.000**	0.284
APQ	4.461	1	0.037	0.046	2.869	1	0.094	0.030	0.268	1	0.606	0.003	12.986	3	**0.000**	0.295
PPQ	0.577	1	0.450	0.006	3.654	1	0.059	0.038	0.001	1	0.978	0.000	13.912	3	**0.000**	0.310
vAm	3.113	1	0.081	0.032	1.944	1	0.167	0.020	0.026	1	0.873	0.000	14.374	3	**0.000**	0.317
NHR	0.164	1	0.686	0.002	0.363	1	0.548	0.004	0.363	1	0.548	0.004	7.704	3	**0.000**	0.199
VTI	0.485	1	0.488	0.005	3.742	1	0.056	0.039	2.916	1	0.091	0.030	0.929	3	0.430	0.029
SPI	3.726	1	0.057	0.039	17.573	1	**0.000**	0.159	0.204	1	0.653	0.002	3.214	3	**0.026**	0.094
G	0.301	1	0.584	0.003	8.602	1	**0.004**	0.085	0.553	1	0.459	0.006	14.871	3	**0.000**	0.324
R	0.006	1	0.939	0.000	3.690	1	0.058	0.038	1.014	1	0.317	0.011	7.088	3	**0.000**	0.186
B	0.154	1	0.696	0.002	6.202	1	**0.015**	0.063	0.021	1	0.884	0.000	18.283	3	**0.000**	0.371
A	0.060	1	0.807	0.001	8.478	1	**0.005**	0.084	1.734	1	0.191	0.018	15.032	3	**0.000**	0.327
S	0.230	1	0.632	0.002	0.316	1	0.575	0.003	3.103	1	0.081	0.032	16.110	3	**0.000**	0.342

Notes: df = degrees of freedom; p = statistical significance; η² = Partial Eta Squared

The effect of gender was statistically significant for the following acoustic characteristics: F0 ($p < 0.001$, $\eta^2 = 0.656$), Fhi ($p < 0.001$, $\eta^2 = 0.602$), Flo ($p < 0.001$, $\eta^2 = 0.493$), STD ($p < 0.01$, $\eta^2 = 0.099$) and PFR ($p = 0.01$, $\eta^2 = 0.070$), while no statistically significant effects were found for any of the perceptual characteristics ($p > 0.05$). Age had a significant effect on vF0 ($p < 0.05$, $\eta^2 = 0.045$) and SPI ($p < 0.001$, $\eta^2 = 0.159$) among the acoustic characteristics, and on G ($p < 0.01$, $\eta^2 = 0.085$), B ($p < 0.05$, $\eta^2 = 0.063$) and A ($p < 0.01$, $\eta^2 = 0.084$) among the perceptual ones. Smoking status showed a significant effect on F0 ($p < 0.05$, $\eta^2 = 0.044$) and Flo ($p < 0.05$, $\eta^2 = 0.059$) but no significant effects on perceptual characteristics ($p > 0.05$). Regarding depression severity, statistically significant effects were observed for nearly all acoustic parameters ($p < 0.05$), except Fhi and VTI ($p > 0.05$), as well as for all perceptual parameters ($p < 0.001$), after controlling for gender, age, and smoking status.

Predictors of depression severity

A hierarchical regression analysis was used to determine the contribution of acoustic voice characteristics in predicting depression severity (Table 10).

Table 10. *Results of hierarchical regression analysis for predicting depression severity (MADRS score) based on acoustic voice characteristics*

Block		β	t	p	R	R^2	F (4/44)	P
1	gender	0.037	0.377	0.707	0.359	0.129	4.730(3/96)	**0.004**
	age	0.187	1.921	0.058				
	smoking status	-0.323	-3.368	**0.001**				
2	gender	0.147	1.021	0.310	0.750	0.563	5.371(15/81)	**0.000**
	age	-0.034	-0.368	0.714				
	smoking status	-0.127	-1.516	0.133				
	F0	-0.658	-1.524	0.131				
	Fhi	-0.271	-0.709	0.480				
	Flo	0.759	1.874	0.065				
	STD	0.067	0.179	0.858				
	PFR	0.519	1.897	0.061				
	vF0	0.016	0.042	0.966				
	Jitt	1.471	1.897	0.061				
	ShdB	-1.334	-1.975	0.052				
	Shim	1.086	1.323	0.189				
	APQ	0.322	0.674	0.502				
	PPQ	-1.235	-1.619	0.109				
	vAm	0.241	2.089	**0.040**				
	NHR	-0.182	-1.095	0.277				
	VTI	0.115	1.341	0.184				
	SPI	0.108	1.151	0.253				

Dependent variable: MADRS score

The hierarchical regression analysis was conducted in two blocks. The first block included sociodemographic variables (gender, age, smoking status), while acoustic voice characteristics were added in the second block along with the sociodemographic variables.

The results show that smoking status was a significant predictor of depression severity in the first block ($\beta = -0.323$, $t = -3.368$, $p < 0.01$). When voice characteristics were added in the second block, none of the sociodemographic variables were significant. However, the peak amplitude variation (vAm) acoustic parameter was found to be a statistically significant predictor ($\beta = 0.241$, $t = 2.089$, $p < 0.05$) of depression severity.

The contribution of perceptual voice characteristics to predicting depression severity was also tested using the hierarchical regression analysis (Table 11).

Table 11. *Results of regression analysis for predicting depression severity (MADRS score) based on perceptual voice characteristics*

Block		β	t	p	R	R^2	F (4/44)	P
1	gender	0.037	0.377	0.707	0.359	0.129	4.730(3/96)	**0.004**
	age	0.187	1.921	0.058				
	smoking status	-0.323	-3.368	**0.001**				
2	gender	0.061	0.967	0.336	0.809	0.654	27.626(5/91)	**0.000**
	age	-0.101	-1.426	0.157				
	smoking status	-0.183	-2.832	**0.006**				
	G	0.292	3.446	**0.001**				
	R	0.025	0.314	0.755				
	B	0.216	2.621	**0.010**				
	A	0.229	2.741	**0.007**				
	S	0.302	4.237	**0.000**				

Dependent variable: MADRS score

Hierarchical regression analysis was conducted in two blocks. The first block included sociodemographic variables (gender, age, smoking status), and in the second block, perceptual voice characteristics were introduced alongside the sociodemographic variables.

The results show that smoking status was a significant predictor of depression severity in the first block ($p < 0.01$). In the second block, when voice characteristics were included, the smoking status variable ($\beta = -0.183$, $t = -2.832$, $p < 0.01$), as well as the perceptual parameters G ($\beta = 0.292$, $t = 3.446$, $p < 0.01$), B ($\beta = 0.216$, $t = 2.621$, $p = 0.01$), A ($\beta = 0.229$, $t = 2.741$, $p < 0.01$), and S ($\beta = 0.302$, $t = 4.237$, $p < 0.001$), were found to be significant predictors of depression severity.

Discussion

Scarce literature available in the Serbian-speaking area suggests that there are statistically significant differences between participants with depression and those in the control group regarding certain voice and speech characteristics, such as parameters of frequency variability, amplitude variability, noise and tremor (Calić et al., 2022a), average intensity values (Ćuk-Jovanović, 2003), utterance duration (Ćuk-Jovanović, 2002), as well as the discriminative role of intensity variability parameters (Calić et al., 2022a). In our study, we aimed to conduct a deeper analysis to explore whether specific voice characteristics (perceptual and acoustic) can predict depression severity (MADRS score) by applying hierarchical regression analysis, incorporating variables that might affect the voice (gender, age, smoking status) and which are described as potential confounders in the literature (Hashim et al., 2017; Wang et al., 2023).

The results of the Kruskal-Wallis test show statistically significant differences in all perceptual and nearly all acoustic voice characteristics, except for F0 and Fhi in the frequency variability domain and the VTI parameter in the noise and tremor assessment domain, between participants with different levels of depression symptoms. The study by Silva et al. (2024), which also employed a sustained vowel phonation task, similarly found that the average F0 parameter did not differ between groups, unlike the Shimmer and Jitter parameters. Since the vocal task involved sustained vowel phonation, pitch-related features such as F0 and Fhi may have been less sensitive to emotional variation, compared to tasks that include continuous speech or reading, where intonation and lexical accentuation are more pronounced. For example, Wang et al. (2019) found that F0 varied across different speech tasks, including answering questions, reading, picture description, and video watching. Additionally, these findings may be partly explained by a gender effect that could have masked the potential impact of depression on these pitch-related features. Given that the Serbian vocal system includes stable phonation with clearly articulated, unreduced vowels (Nikolić, 2016), the VTI parameter, which measures the turbulent component of the voice signal, might not show significant differences precisely because of phonetic stability and the nature of the vocal task. However, it is also possible that these specific acoustic parameters are not sufficiently sensitive markers for detecting depression-related vocal changes. A more precise post hoc analysis revealed significant differences between participants without depression and those with depression, as expected. However, surprisingly, there were no significant differences in acoustic voice characteristics between participants with mild, moderate, and severe depression, while significant differences were found in perceptual voice characteristics. Differences were observed between participants with mild and severe depression (all analyzed perceptual parameters) and between participants with moderate and severe depression (roughness and breathiness), but not between participants with mild and moderate depression. This potentially indicates that the voice of participants with different levels of depression severity conveys a subjectively different auditory impression, which is why it is also important to analyze the acoustic correlates. A recent study (Menne et al., 2024) showed that the Shimmer parameter had higher average values in participants with moderate depression compared to those with mild depression. However, the differences were not statistically significant, as in our study. One of the scarce studies (Shin et al., 2021) that included participants with minor depression found that only the standard deviation of the fundamental frequency (STD) parameter differed between participants with minor and major depressive disorder out of the 21 analyzed characteristics.

Additionally, gender was found to significantly influence frequency variability parameters (F0, Fhi, Flo, STD and PFR), which is consistent with known physiological differences in vocal fold size and tension between males and females (Abitbol et al., 1999). This biological influence may overshadow subtle emotional effects on pitch. Smoking status also showed a significant effect on F0 and Flo, while age appeared to influence acoustic parameters vF0 and SPI, as well as perceptual voice characteristics (G, B,

and A). These findings are in line with Songur et al. (2025), who reported that age, rather than gender, influences perceptual voice characteristics, and with previous studies indicating an effect of smoking on F0 parameters (Ayoub et al., 2019). Nevertheless, the MANCOVA analysis indicated that depression severity significantly affected most acoustic (except Fhi and VTI) and all perceptual voice characteristics, even after controlling for gender, age, and smoking status. While Kruskal–Wallis analysis did not show group differences in F0, MANCOVA revealed a significant effect of depression severity on this parameter after controlling for gender, age, and smoking. This suggests that the effect of depression on F0 may be masked by stronger demographic influences, particularly gender. These findings point to a potential independent effect of depression severity on voice characteristics, beyond the influence of demographic variables such as age, gender, and smoking status. In other words, even after statistically controlling for variables known to affect voice parameters, differences in both acoustic and perceptual voice characteristics remained significant across levels of depression severity. This suggests that changes in voice may not be solely attributable to demographic factors, but could also reflect underlying psychopathological processes associated with depression. However, caution is warranted when interpreting these findings, as the cross-sectional nature of the study limits causal inferences.

The hierarchical regression analysis showed that among acoustic voice characteristics, the peak amplitude variation (vAm) from the second block was a significant predictor of depression severity (MADRS score). Although the smoking status variable was significant in the first model, it was not significant in the second model after adding acoustic voice characteristics, nor were the gender and age variables. These results are inconsistent with the results of multiple linear regression obtained by Silva et al. (2024), indicating that the Jitter parameter and the smoothed cepstral peak prominence were the predictors of depression. A possible explanation for this difference is that they used the Beck Depression Inventory, which is more focused on cognitive symptoms (Ignjatović Ristić et al., 2012; Kiss and Jenei, 2020), and they also had a higher proportion of participants with severe depression in their sample. High variations in peak-to-peak amplitude are associated with hypofunctional phonation, characterized by loose adduction (Laukkanen and Sundberg, 2008). Loose and shorter vocal folds, associated with lower F0, reduce adduction and thereby increase the amplitude of vocal fold vibrations (Laukkanen and Sundberg, 2008). Previous study (Calić et al., 2022a) also found that the peak amplitude variation parameter (vAm) had the highest discriminative value for the group of participants with depression, along with the amplitude perturbation quotient parameter (APQ) from the same domain. In the present study, APQ did not prove to be a significant predictor. However, the Shimmer in dB parameter (ShdB), which is related to APQ, was close to statistical significance. In a study by Quatieri and Malyska (2012), Shimmer was also found to be associated with depression severity measured by the HAMD scale, while Jitter was not significantly correlated. Future studies on larger samples that include an equal number of participants with different levels of depression severity could provide more precise significance.

In the group of perceptual voice characteristics, the significant predictors of depression severity were the G (hoarseness), B (breathiness), A (asthenia), and S (strain) parameters. Sahu and Espy-Wilson (2016) suggest that the vocal quality in depression is characterized by breathiness and creakiness, based on higher values of Jitter and Shimmer parameters. Wang et al. (2019) emphasize that vocal quality in depression may be characterized by vocal weakness due to the association between fundamental frequency parameters and overall muscle tension. In the model that includes perceptual voice characteristics, unlike the acoustic ones, smoking status emerged as a significant predictor of depression severity, while gender and age were not significant predictors in either model.

The obtained results confirm the existing literature on the predictive role of acoustic voice characteristics for depression, but they also preliminarily strengthen it by emphasizing the significant role of perceptual voice characteristics. Our study has several limitations. The first refers to the sample size, which should be larger in future studies to validate the results. It is important to increase the number of participants within each subgroup, especially those with severe depression, to improve the reliability of the regression analysis and reduce the risk of Type II error. Also, the sample should be expanded to include participants from different regions, and stratified random sampling should be applied to control groups to improve the generalizability of the results. Another limitation of the study is the lack of uniformity of the sample with respect to smoking status, in addition to gender and age, which may affect the generalizability of the results. Studies suggest that the prevalence of smoking is approximately twice as high among individuals with depression compared to those without (Lasser et al., 2000; Stubbs et al., 2018). Therefore,

it is important to control for the influence of smoking status in future research. In addition to the included perceptual and acoustic parameters indicating vocal quality, vocal analysis should also integrate other parameters, such as prosodic (e.g. speech rate, pause time), spectral and cepstral analyses, to introduce parameters with different properties. One limitation of the current study is the exclusive use of a sustained vowel phonation task, which, although widely used in acoustic analysis, may not fully capture the variability in prosodic features typically observed in continuous speech. Given that different voice tasks were selected based on their suitability for acoustic and perceptual analyses, future studies may assess whether the findings remain consistent across different tasks and analyses, including comparisons of the same task evaluated through both acoustic and perceptual methods.

Future research should focus on comprehensive vocal analysis using a large sample of participants, incorporating a wider range of parameters and diverse speech tasks (e. g., reading, sustained vowel, continuous speech) to evaluate the consistency and generalizability of prediction results. It would also be important to compare these results with findings from studies in other languages. Furthermore, the effect of medication on the voice should be explored, along with smoking and coffee consumption, which may alter the therapeutic effects of medication (Radmanović et al., 2017). In future research, participants should be followed longitudinally to monitor voice characteristics across clinically relevant stages, from diagnosis and treatment response to relapse. It would be significant to identify causal factors associated with voice characteristics specific to depression. Since depression is associated with heterogeneous factors, it would be significant to examine the role of individual factors to assess the contribution of intraindividual factors to the voice. Given that psychomotor slowing and agitation may have opposing effects on speech and voice characteristics, future studies should consider examining their individual contributions, potentially by dividing participants into subgroups based on dominant symptoms. Therefore, future research should move towards creating more complex machine-learning models and neural networks that determine both inter- and intraindividual differences to deepen these knowledge. These models should take into account sample size, demographic characteristics, languages, analyzed parameters, speech tasks, and depression scale assessments when creating algorithms. Moreover, fostering multidisciplinary collaboration among psychiatrists, speech therapists, psychologists, and AI engineers could be important to better harness the potential of voice analysis in depression. Such advances may help standardize vocal analysis in depression and enable automatic voice recognition systems to serve as interdisciplinary tools supporting early diagnosis and treatment monitoring.

Conclusion

This study represents the first known attempt to identify depression severity predictors based on voice characteristics in the Serbian-speaking area. Hierarchical regression analysis shows that the acoustic parameter of amplitude peak variation (vAm) and perceptual parameters of hoarseness, breathiness, asthenia, and strain have significant predictive value in determining depression severity. These preliminary findings indicate that voice characteristics hold promise for predicting depression severity (MADRS score). Further research is needed to address the limitations of this study and to ensure generalizability. The obtained results support the potential incorporation of both perceptual and acoustic characteristics (specifically from the domain of intensity variability) within a depression recognition model. If confirmed in larger samples and with more rigorous methodologies, such a model could have important diagnostic and therapeutic implications in clinical practice.

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Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, G.C., B.R., M.P.L., D.I.R., N.S. and M.M.; methodology, G.C.; investigation, G.C. and B.R.; software, M.P.L.; formal analysis, G.C.; writing—original draft preparation, G.C. and B.R.; writing—review and editing, G.C., B.R., M.P.L., D.I.R, N.S and M.M. All authors have read and agreed to the published version of the manuscript.

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The Effect of Emotional Charge of Visual Stimuli on Memorization and False Recognition

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Abstract: Various sensory stimuli, including visual ones, carry certain emotional characteristics. Given that the brain continuously processes a vast number of sensory inputs, inevitably, memory and emotions are intrinsically linked. This study aims to explore the connection between experience and cognitive performance. Through a quantitative experimental design, it has been demonstrated that individuals are more likely to remember emotionally charged visual stimuli compared to neutral visual stimuli. Additionally, a significant effect of emotional charge on memory recall was identified, with a positively charged stimuli being remembered more effectively than neutral ones. From the perspective of specific emotional charge, a preference for greater enjoyment of positively charged emotional stimuli over negatively charged ones was also observed. However, the effect of emotional charge on the occurrence of false associations was not confirmed, as no differences in false associations were found between emotionally charged and neutral visual stimuli. This knowledge can enhance our understanding of cognitive processes within the Slovak population and may serve as a foundation for future research in the field of cognitive sciences.

Keywords: *emotional charge, false recognition, memory, remembering, visual stimulus.*

Introduction

Emotions are present in nearly every moment of people's daily lives, adding depth to their experiences with the world. The objects individuals encounter serve as carriers of specific emotional characteristics that can evoke a range of emotions, depending on the individual's personal experiences and psychological state. Emotions are influenced by a network of interconnected structures in the brain known as the limbic system (Rajmohan and Mohandas, 2007). These structures are intrinsically linked to cognitive abilities and influence cognitive processes such as attention, memory, and executive functions. Memory and emotions are fundamentally linked, as both involve brain activity (Phan et al., 2002). Pilarczyk and Kuniecki (2014) indicate that emotionally charged stimuli are prioritized during processing, and memory retention is enhanced for such stimuli (Harris and Pashler, 2005). However, this study focuses only on events and words with an emotional charge. Furthermore, it has confirmed that memory for emotionally charged words, particularly negative ones, is superior to that for neutral words (Harris and Pashler, 2005). Other studies suggest that adults tend to prefer and remember positive stimuli more than negative stimuli, as they are generally more recognizable, as the left hemisphere is particularly involved in processing positive emotional stimuli during memory tasks (Balcony and Ferrari, 2012; Madan, Scott and Kensinger, 2019). Conversely, some studies (Harris and Pashler, 2005; Quevedo et al., 2003) suggest that emotionally charged stimuli may lead to reduced memory retention rather than enhancement. Quevedo et al. (2003) demonstrated that the positive effects of emotions on memory become evident only after extended retention intervals, with no significant differences observed during shorter intervals.

Research indicates that emotional stimuli tend to evoke more false memories than neutral stimuli, and individuals are more likely to falsely remember negative stimuli than positive or neutral ones (Dehon et al., 2010). The state in which a non-presented object elicits an illusory sense of recollection is referred

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to as phantom memory or false memory (Gong et al., 2016). The prefrontal cortex plays a significant role in this process, as it is partially responsible for encoding, searching, and evaluating memories (Johnson, 2001). Zheng et al. (2019) found that false recognition memory shows a preference for positive over negative emotional stimuli, indicating that false recognition is more likely to occur with positive emotional stimuli. Another study revealed that the false recall effect occurs even more frequently for negatively valenced stimuli than for those with positive valence (Dehon et al., 2010). One of the most common explanations is that the influence of affective charge causes a narrowing of attention, leading to selective memory and memory illusions, as individuals tend to better memorize the central details during negative arousal but have poorer encoding of peripheral information, which creates a foundation for memory distortions (Kensinger, 2009).

The study by Carstensen et al. (2003) suggests that age significantly affects the processing of visual stimuli in the adult population (Isaacowitz et al., 2006), referencing the theory of socioemotional selectivity. This theory posits that age serves as a predispositional factor in a motivational shift toward emotional goals. However, most studies examining the impact of emotional visual stimuli on memory have mostly focused on either childhood or the period of middle to late adulthood; consequently, there is a notable lack of research investigating the effects of emotional static visual stimuli in young to middle adulthood. Overall, the findings regarding emotional stimuli and their effect on memory are contradictory. Additionally, there is insufficient evidence related to the recall of emotionally charged or neutral stimuli in the Slovak population, as well as a lack of studies focused on the false recognition of visual stimuli potentially influenced by Slovak culture.

In this study, we examine stimuli that require temporary storage but have already undergone the storage process. This suggests that these stimuli have entered long-term memory through memorization. Empirical evidence indicates that emotions can enhance long-term memory; however, they can also have a detrimental effect by reducing the quantity of remembered information or by distorting, leading to false recognition (Zheng et al., 2019). The ambiguous effects of emotional stimuli can be further investigated by presenting the stimuli and recording their re-recognition.

Objectives of the study

The relationship between emotional visual stimuli and their impact on memory retention and false recognitions is quite complex, and the findings show inconsistency. Therefore, several research goals were established to enhance the understanding of experience and cognitive performance:

- Identify the effect of the emotional charge of visual stimuli on memory retention.
- Verify the differences in memorization between emotionally charged visual stimuli and neutral visual stimuli.
- Identify the differences in the number of false associations when recognizing emotionally charged and neutral visual stimuli.

Based on the previous research findings and current research objectives, the following hypotheses were formulated:

1. We assume that individuals will remember emotionally charged visual stimuli more effectively compared to neutral visual stimuli.
2. We assume that individuals remember positive emotional stimuli more effectively than negative emotional stimuli.
3. We assume that when re-recognizing emotionally charged visual stimuli, there will be more false associations than when visual stimuli are neutral.
4. We assume that with positive emotional stimuli, there are more false associations than with negative emotional stimuli.

Materials and Methods

Research sample

The research sample consisted of 38 participants. The sample size was selected to align with the sample sizes of similar studies (e.g., Quevedo et al., 2003; Gong et al., 2016; Maksimainen et al., 2018). A non-random method was selected, and individual participation was voluntary. All participants were psy-

chology students from a university in Slovakia. In terms of gender differences, there was a notable predominance of females in the study (n = 30) over males (n = 8). The mean age of the total sample was 26.16 years (SD = 7.32). The mean age for males was 30.38 years (SD = 9.58), while the mean age of females was significantly lower at 25.03 years (SD = 6.33). The youngest participant in the study was 21 years old for both genders, and the oldest participant was 48 years old among females and 46 years old among males.

Procedure

A within-subject design was implemented, and each participant was exposed to all three levels of the independent variable – positive, negative and neutral emotional stimuli. The dependent variable in this study was memorization. This study consisted of three parts: presentation, memory, and verification. The emotional stimuli were subsequently categorized into photographs with a positive emotional valence and those with a negative emotional valence. Ultimately, emotional valence encompassed three different levels (neutral, positive, and negative). The stimuli were selected from the GAPED database, an internationally recognized database (Dan-Glauser and Scherer, 2011) that has been demonstrated to be a reliable database with proven validation of affective stimuli (Balsamo et al., 2020). The use of photographs from the GAPED database was contingent upon guidelines permitting users to utilize the database for research purposes, allowing researchers to share (copy, transfer) and remix (adapt) the source materials (Dan-Glauser and Scherer, 2011). Photographs were selected for each category primarily based on their determined valence, which is a fundamental factor in the experimental stimuli. The key stimuli comprised 15 photographs. In the presentation phase, visual stimuli of negative valence included images A024, A039, A059, Sn022, and Sp036 from the GAPED database (Dan-Glauser and Scherer, 2011). The positive stimuli category included photographs P017, P031, P037, P077, P081, and P114, while neutral stimuli were represented by photographs N011, N020, N061, N081, and N089. For photographs with a negative emotional charge, ethical considerations were taken into account, including adherence to valid internal (moral) norms, with an average score of 41.05, and external (legal) norms, with an average score of 50.33. The database is constructed in such a way that positive and negative objects are animate, and neutral objects are mainly inanimate, due to the need for the absence of affective valence. All photographs were uniformly sized at 640x480 pixels. The visual stimuli included in the first part of the study are shown in Figures 1, 2, and 3. Three versions with different arrangements of stimuli were created to demonstrate that the order of the photographs does not influence the participants' ability to recall the stimuli. The visual stimuli (photographs) were presented to participants via Microsoft PowerPoint in full-screen mode on a computer screen. Each slide contained one image, and the slides were automatically advanced at fixed intervals. Participants were seated approximately 60 cm from the display and were instructed to remember the scenes as accurately as possible. Head movements were not restricted. Throughout the experiment, a white fixation point appeared on a grey background in the center of the screen for 2 seconds. The fixation point was placed in the center of the screen, and photographs with varying affective charges were presented in the middle of the screen. Each photograph was displayed for 6 seconds. Following the presentation part, a countdown from 15 to 1 was shown on the monitor screen, after which memory performance was assessed. During the memory part, participants were asked to describe the scenes they had observed in the presentation phase in any order they wished. This memory phase was not time-limited and lasted an average of 13 minutes. The verification and re-recognition phase included a total of 36 visual stimuli arranged in an identical layout, consisting of 12 stimuli for each type of emotional charge. This phase featured 15 stimuli from the presentation phase and 21 new stimuli of similar valence. In the verification phase, participants indicated whether they had seen each photograph during the presentation phase. They were given 7 seconds to respond to each photo. Given that previous research has shown that emotional stimuli tend to elicit more false memories than neutral stimuli and can also impair memory based on their valence (Dehon, Larøi, and Van der Linden, 2010), which is characterized as false recognition (Zheng, et al., 2019). This additional section was considered beneficial for validating false recognition.

Figure 1. Visual stimuli - photographs with a negative emotional charge (Dan-Glauser and Scherer, 2011)

Figure 2. Visual stimuli - photographs with a positive emotional charge (Dan-Glauser and Scherer, 2011)

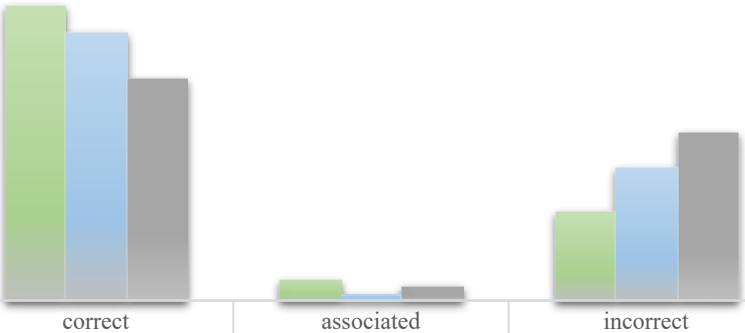
Figure 3. Visual stimuli - photographs with a neutral emotional charge (Dan-Glauser and Scherer, 2011)

In terms of ethical considerations, it was essential to ensure the objectivity and neutrality of the experimenter while safeguarding sensitive data. Participants in the experiment were informed about the purpose of the research, data protection measures and were provided with an informed consent form to sign before the experiment commenced. This form emphasized ethical principles and participants' right to withdraw from the study at any time. Each participant had taken part in the experiment individually but under the supervision of an experimenter, who guided them throughout the experiment. The experiment lasted for approximately 30 minutes. The laboratory experiment was followed by a content analysis of the text. The content analysis included three analytical categories: correct, associated, and incorrect responses. A three-point scoring system (0 - incorrect, 1 - associated, 2 - correct response) was developed to capture scores for remembered stimuli with specific emotional charge, as well as scores for false

associations across the three types of emotional charge. During the verification phase, responses were classified as either correct or incorrect.

Results

All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics, repeated-measures ANOVA, and paired-samples t-tests were employed to test the stated hypotheses. Effect sizes were reported using partial eta squared (η^2) for ANOVA and Cohen's d for t-tests, following conventional interpretation thresholds. The use of established analytical procedures and statistical software contributes to the methodological transparency and reproducibility of the study (Field, 2013). In terms of describing the different categories of emotional charge *(hereafter referred to as "ECH"),* the category of photos with a positive ECH was the most frequently recalled, yielding a total number of 138 correct responses. This was followed by the category with a negative ECH, with 125 correct responses. The least accurately remembered were the neutral photographs, with only 104 correct responses. The mentioned scores can be seen in Graph 1. Between the positive and negative visual stimuli, there was a difference of 13 correct responses, favoring the positive ones. The greatest number of incorrect responses was recorded in the neutral ECH category.



	correct	associated	incorrect
positive	138	10	42
negative	125	3	62
neutral	104	7	79

Graph 1. Correctness of answers for three types of emotional charge

To evaluate the assumption of normality, visual inspection through Q-Q plots and histograms was conducted. Given the sample size (N = 38), visual methods were considered more reliable than numerical tests (Field, 2013). The visual inspection did not indicate substantial departures from normality. Therefore, the use of parametric tests (ANOVA and paired-samples t-tests) was deemed appropriate.

To test the first hypothesis, which assumed that emotionally charged visual stimuli would be remembered more effectively than neutral stimuli, a repeated-measures ANOVA was conducted to examine the effect of stimulus valence (positive, negative, neutral, and emotional overall) on the accuracy of participants' responses. The assumption of sphericity was violated, as indicated by Mauchly's test, W = .000, χ^2 (5) = 10.149, p = .006; thus, the Greenhouse–Geisser correction was applied. The analysis revealed a statistically significant main effect of valence, F (1.61, 59.41) = 8.37, p = .001, partial η^2 = .184, indicating that the type of stimulus significantly influenced memory performance.

To further examine the nature of this effect, polynomial contrasts were conducted (see Table 1). A significant linear trend was observed, F (1, 37) = 14.31, p = .001, partial η^2 = .279, suggesting a consistent difference in memory performance across stimulus types. Additionally, a significant quadratic trend was found with the same F-value and effect size, indicating non-linear variation. The cubic trend approached significance, F (1, 37) = 3.75, p = .060, partial η^2 = .092.

Table 1. *Results of Polynomial Contrasts for the Effect of Valence (Repeated Measures ANOVA)*

Contrast Type	SS	df	MS	F	p	Partial η²
Linear	2.158	1	2.158	14.313	.001	.279
Quadratic	10.791	1	10.791	14.313	.001	.279
Cubic	4.200	1	4.200	3.751	.060	.092

Note: SS = Type III Sum of Squares, MS = Mean Square, η² = Eta squared

Descriptive statistics showed that participants achieved the highest average score in the category of positive stimuli (M = 3.63, SD = 1.03), followed by emotionally charged stimuli (M = 3.46, SD = 0.90), negative stimuli (M = 3.29, SD = 1.01), and neutral stimuli (M = 2.74, SD = 1.03). These results support the hypothesis that emotionally charged visual stimuli are better remembered than neutral ones.

The difference in the scores of correct answers between emotionally charged and neutral stimuli was statistically significant ($p < 0.05$). The mean score of differences for the various types of emotional charge was 0.724 (SD = 1.441), as can be seen in Table 2. These results support the hypothesis that emotionally charged visual stimuli are remembered more effectively by individuals than neutral visual stimuli. An effect size of 0.745 was observed between neutral and emotional visual stimuli, which, according to Cohen's criteria, can be classified as a medium effect size of emotional charge on recall (Sullivan and Feinn, 2012). Degrees of freedom (df) in this analysis were 37. The "df" is indicated in the table next to the value of the t-test (t) in parentheses.

Table 2. *The result of the paired t-test - hypothesis no. 1 - the average differences in the score of correct responses*

		M	SD	t (37)	p	Cohen's *d*
Pair 1	Positive emotional charge Neutral emotional charge	0.895	1.521	3.627	0.001	0.865
Pair 2	Negative emotional charge Neutral emotional charge	0.553	1.519	2.242	0.031	0.538
Pair 3	Emotional charge Neutral emotional charge	0.724	1.441	3.095	0.004	0.745

In Hypothesis 2, we assumed that individuals will remember positive emotional stimuli more effectively than those of negative emotional stimuli. The differences in mean score for different types of emotional charge is statistically significant ($p < 0.05$), with a mean difference of 0.342 (SD = 0.966).

The results of the t-test (as shown in Table 3) support the hypothesis that individuals remember positive emotional stimuli more effectively than negative emotional stimuli. The effect of emotional charge on remembering has a value of Cohen's $d = 0.334$, indicating a small effect size.

Table 3. *The result of the paired t-test - hypothesis no. 2 – the average differences in the score of correct responses*

		M	SD	t (37)	p	Cohen's *d*
Pair 1	Positive emotional charge Negative emotional charge	0.342	0.966	2.182	0.036	0.334

In Hypothesis 3, we assumed that when re-recognizing emotionally charged visual stimuli, there would be more false associations than when visual stimuli are neutral. Descriptive statistics in identifying the difference in memorization and false recognition revealed a total of 55 false associations, accounting for 4.02% of all responses.

To complement the t-test analyses, a repeated-measures ANOVA was conducted to examine whether the number of false associations differed significantly depending on the emotional valence of the stimuli (neutral, positive, and negative). Mauchly's test indicated a violation of the assumption of sphericity, $\chi^2 (2) = 10.553$, $p = .005$. Therefore, the Greenhouse–Geisser correction was applied. The analysis did not reveal a statistically significant main effect of valence, $F (1.60, 59.41) = 0.519$, $p = .557$, partial $\eta^2 = .014$, suggesting that the emotional charge of stimuli did not significantly affect the frequency of false associations.

Polynomial contrasts further confirmed the absence of significant trends: the linear trend was non-significant, $F (1, 37) = 1.207$, $p = .279$, $\eta^2 = .032$, as was the quadratic trend, $F (1, 37) = 0.107$, $p = .745$, $\eta^2 =$

.003 (see Table 4).

Table 4. *Results of repeated-measures ANOVA - hypothesis no. 3 – false associations by emotional valence*

Effect	df (GG)	F	p	Partial η²
Valence (Greenhouse-Geisser)	1.60, 59.41	0.519	.557	.014
Linear Contrast	1, 37	1.207	.279	.032
Quadratic Contrast	1, 37	0.107	.745	.003

Descriptive statistics showed that the mean number of false associations was lowest for neutral stimuli (M = 0.42, SD = 0.64), slightly higher for positive stimuli (M = 0.45, SD = 1.08), and highest for negative stimuli (M = 0.58, SD = 0.72). Pairwise comparisons between the types of stimuli showed no significant differences (all p > .05), consistent with the t-test findings.

To further explore potential pairwise differences in false associations, we conducted series of paired t-tests was also conducted to analyze three stimulus pairings based on the research hypothesis. The results presented in Table 5 did not reveal statistically significant differences (all p > .05) in false associations between neutral visual stimuli and either positively or negatively charged stimuli, nor between neutral and overall, emotionally charged stimuli.

Table 5. *The result of the paired t-test - hypothesis no. 3 – score of false associations*

		M	SD	t (37)	p	Cohen's *d*
Pair 1	Positive emotional charge Neutral emotional charge	0.026	0.885	0.183	0.856	1.034
Pair 2	Negative emotional charge Neutral emotional charge	0.158	0.886	1.098	0.279	0.234
Pair 3	Emotional charge Neutral emotional charge	0.092	0.624	0.909	0.369	0.141

These results do not support Hypothesis 3, which predicted that emotionally charged visual stimuli would elicit a greater number of false associations than neutral stimuli. Both the ANOVA and paired-samples t-tests consistently indicated no statistically significant differences in the number of false associations across stimulus valence conditions.

In Hypothesis 4, we assumed that there would be more false associations with positive stimuli than with negative emotional stimuli. In the analysis of spurious associations between different ECH types, the mean difference is -0.132 (SD = 1.26). The paired-samples t-test revealed no statistically significant difference between positive and negative emotional stimuli in the number of false associations, t(37) = -0.646, p = .522, Cohen's d = 0.141 (see Table 6).

Table 6. *The result of the paired t-test - hypothesis no. 4 – score of false associations*

		M	SD	t (37)	p	Cohen's *d*
Pair 1	Positive emotional charge Negative emotional charge	-0.132	1.256	-0.646	0.522	0.141

These results do not support the assumption that there will be more false associations with positively charged emotional stimuli than with negatively charged emotional stimuli.

Discussions

The study examined the effect of the emotional charge of visual stimuli on memory retention and the occurrence of false associations during re-recognition. In the first hypothesis, we assumed that individuals will remember emotionally charged visual stimuli more effectively than neutral visual stimuli. The findings showed that individuals were able to remember more emotional stimuli than neutral ones, which is consistent with previous research (Humphreys et al., 2010; Pilarczyk and Kuniecki, 2014). From a cognitive psychology perspective, enhanced recall can be attributed to the inherent salience of affective stimuli, which capture more attention than neutral stimuli. Consequently, individuals tend to allocate greater attention during the encoding process when focusing on emotional items (Talmi et al., 2008).

Furthermore, the social context may also be a contributing factor in shaping past emotional experiences, leading individuals to exhibit a stronger inclination towards emotional stimuli (Maksimainen et al., 2018). However, it is important to note that the perception and processing of emotional information are also shaped by cultural background. Cross-cultural studies have shown that attentional patterns, emotional salience, and even neural processing differ across cultures. For example, individuals from Western, individualist cultures tend to focus more on personal emotional experiences and discrete emotional expressions, whereas individuals from East Asia are more likely to consider social context and may regulate or suppress emotional responses accordingly (Matsumoto et al., 2008).

Finally, the neuropsychological basis for improved memory of emotional stimuli lies in brain function. Emotions trigger high-frequency brain waves in the amygdala, a key brain structure responsible for heightened activation of cognitive functions (Kensinger, 2009). When an individual perceives an emotional component, the amygdala is activated, resulting in the production of adrenaline, which in turn stimulates the hippocampus, enhancing the encoding of emotional memories (Tambini et al., 2016). During emotionally charged events, the brain releases neurotransmitters such as adrenaline and cortisol, which facilitate encoding and recall. In simple terms, people are drawn to the emotional intensity and vividness that emotions evoke, leading them to remember emotional stimuli more effectively than neutral stimuli. Ultimately, the effect of emotional intensity on memory retention is due to a complex interplay among neurochemical, cognitive, social, and neural factors.

In the second hypothesis, we assumed that individuals would remember positive emotional stimuli more effectively than negative emotional stimuli, which was confirmed by our results and individuals remembered positive emotional stimuli more effectively than negative emotional stimuli. Our findings demonstrated that they are in line with previous research, which has confirmed that positive emotional content creates stronger memory traces, leading to higher memorability (Bessette-Symons, 2017; Zheng et al., 2019). Positive emotional stimuli tend to remain in the memory longer and are recalled more frequently than negative emotional stimuli. This phenomenon may be attributed to the brain's response to positive emotional stimuli, which triggers the amygdala to release hormones such as dopamine and serotonin. These neurotransmitters enhance the individual's ability to remember the stimulus more vividly (Kelly, 2017). One possible explanation for why individuals exhibit better memory for positively charged stimuli is an intrinsic desire to maintain a positive outlook on life, as well as an effort to forget the unpleasant experiences. Additionally, emotional mood can significantly impact memory retention. Research has demonstrated that a positive mood enhances recall and overall memory performance (Osaka et al., 2013). An increasing amount of research highlights the benefits of positive emotions for both mental and physical health (Catalino et al., 2014). Positive emotions broaden perceptual and cognitive horizons compared to negative emotions, encouraging individuals to focus on the bigger picture, while negative emotions often lead to focusing on details, which can result in forgetting (Madan et al., 2018). Sedikides and Skowronski (2020) describe the preference for positive content over negative as the triumph of good over evil, where the inclination towards positivity prevails. This perspective is particularly relevant in today's world, which is often inundated with negative news. Individuals may strive to seek out and retain as many positive stimuli as possible to help preserve their mental health and to prevent the onset and progression of depressive and anxiety disorders. A preference for positive stimuli may be associated with an inclination toward positive emotionality and enhanced psychological and social resources. By focusing on and remembering positive experiences, individuals can attract positivity into their lives, leading to greater happiness. In a simplified view, positive emotions play a crucial role in achieving social goals. Paakkanen et al. (2021) state that experiencing joy, contentment, and other positive emotions contributes to the development of lasting psychological, social, and intellectual capital, including increased resilience and psychological well-being. From a social perspective, emotional stimuli can be utilized to elicit positive emotions, thereby modifying mood and enhancing the experience of positive affect. This approach may enable individuals to recover more effectively from adversity and foster a more optimistic mindset. Ultimately, positivity can lead to greater inner balance, reduced stress, and improved well-being, all of which contribute to enhanced focus. When one's thoughts remain anchored, attention is retained, and memory is improved. Cultural differences also play a role in how individuals perceive and remember positive emotional stimuli, as emotional regulation and expression can affect memory retention. In some cultures, there's a strong emphasis on positivity, while others may adopt a more reserved or balanced approach to emotional expression. Research has indicated that individuals from societies, like those in East Asia, might not focus as much

on positive emotions as those from Western cultures, where personal happiness and positive experiences are often prioritized (Oishi et al., 2007). Similar results were found in Poland, which may be considered a culturally similar country to Slovakia, indicating that positive stimuli were better recalled than negative ones (Paulewicz et al., 2015). These cultural differences can affect not only how individuals process emotional stimuli but also how they encode and recall memories associated with positive emotions, hence our results should be interpreted with caution.

The final sub-goal was to identify the differences in the frequency of false associations when re-recognizing emotionally charged versus neutral visual stimuli. The results of the research study did not support the hypothesis that there would be a higher incidence of false associations when re-recognizing emotionally charged visual stimuli compared to neutral ones (Bessette-Symons, 2017; Dehon et al., 2010; Kensinger, 2009), nor did they indicate a significant difference between positively and negatively charged emotional stimuli. Non-significant results may be because false associations can arise from a variety of factors, including the way information is processed and acquired, individual differences in memory abilities, and cognitive biases. While emotional stimuli may be more memorable and attention-grabbing, this does not necessarily mean that they are more prone to false associations or memory distortions. One possible explanation for the similar rates of false associations is that emotional stimuli are both more engaging and more salient, making them easier to distinguish from similar but unrelated stimuli. This phenomenon may reflect the emotional enhancement of memory, where emotional content improves recognition ability. Furthermore, emotional content is often remembered and subsequently recalled more effectively than non-emotional content. Consequently, emotional stimuli may be beneficial in the workplace or educational settings. Emotional content could not only enhance memory retention but also help prevent students from confusing different materials and topics, thereby leading to improved memory and ultimately, better learning outcomes. Additionally, textbooks and study materials could be enriched with emotional content following further investigation and validation of these findings, as emotions appear to enhance memory without negatively impacting discriminative ability. However, it is necessary to consider that another possible reason for these results may be that the participants are students who regularly engage in memory training for their studies or work. Cognitive training promotes memory reliability. Moreover, psychologists may be hypothetically more resistant to the influence of emotionality on their cognitions. Nevertheless, since the participants were psychology students only rather than working professionals, this factor may be less relevant.

This knowledge is also crucial for investigating culture. Throughout an individual's life, culture shapes their values, goals, and behaviors, which can influence various cognitive processes, including memory and attention (Leger and Gutchess, 2021). Memory functions are also culturally conditioned and affected by cognitive processes. Additionally, there are differences in social norms and in the stimuli that elicit different responses. In some cultures, expressions of anger, violence, and poor treatment of animals may be perceived as more acceptable and viewed more positively than in others, such as in Europe. Similarly, individuals may be influenced by their family background to prioritize a certain emotional response. As our world becomes increasingly interconnected, it is essential to understand the systematic differences in cognitive functions across cultures. Within Europe, particularly in Slovakia, there has been insufficient attention to this issue. The influence of emotional content on memory and false recognition has not been studied yet, resulting in a lack of knowledge about this phenomenon in the country. Exploring this phenomenon is vital for societal advancement, enabling even smaller countries to elevate their standards and contribute scientifically to the understanding of phenomena across different cultures and countries.

The findings of the study are also important from an artistic perspective. For visual artists and photographers, this underscores the importance of creating works that evoke strong emotional responses. Art that captures or evokes emotions (whether positive or negative) is more likely to stay in the viewer's memory and have a lasting impact. The contrast between positive and negative emotional content can be an effective artistic strategy, used to evoke diverse responses, explore the complexity of human emotions, or convey specific narratives. Artists' focus on creating artwork with uplifting, hopeful, or joyful themes can be especially important in contemporary art and photography, where positive emotions are often used to counterbalance social stress or negativity.

The main limitation of this study is the heterogeneity of the research sample, which consists of a high number of young adults compared to a limited representation of individuals in middle adulthood. However, given that research on this phenomenon is still in its early stages in the country, this sample size may be considered sufficient and appropriate. In addition, unassessed long-term mental states of the

participants, especially from a long-term perspective, may pose a threat to internal validity. Nevertheless, it can be concluded that individuals worldwide exhibit different mental states, which is a natural aspect of humanity; thus, this threat is unlikely to significantly impact the results of the study. Furthermore, the participant's attitudes or motivations toward the experiment, as well as their memory performance, could present challenges. The intellectual capacity of the individuals involved could not be assessed in advance, primarily due to time constraints. However, given the selection criteria for the research sample, it is expected that the students' intellectual abilities fall within the normative range. Participants were also motivated by their genuine interest in contributing to scientific knowledge through their involvement in the study.

This research study contributes to our understanding of how the emotional charge of various stimuli can affect a person's cognitive abilities and memory performance. Since memory plays a key role in various everyday settings, such as the workplace and educational settings, individuals can improve their learning and memory retention by associating positive emotional values with the material they perceive. In practice, fostering a positive environment in schools or workplaces is beneficial. Such an environment can be created by the use of pleasant or cheerful images. In educational settings, positive emotions can be integrated into the content presented to students. The key is to link stimuli to enjoyable experiences that evoke pleasure and satisfaction, thereby enhancing students' ability to remember what they have learned. Additionally, memorization can be improved by listening to uplifting music or by experiencing a favorite scent that elicits positive feelings in individuals.

The study could serve as a foundation for further research in the field of investigating emotions and memory, which remains a significant challenge. Given that culture influences how emotions are perceived and experienced, as well as the information people remember, it is important to examine cross-cultural differences in order to understand the effects of emotions on memory retention across various cultural contexts. Research reflecting on these effects in clinical practice, education, or professional settings could further enhance our understanding of the role of emotional content in memory. Finally, this study could inspire the development and standardization of a database of visual stimuli characteristic of the Slovak environment, including the emotional valence of individual objects.

Conclusions

The purpose of this study was to explore the association between emotional experience and cognitive performance. Numerous factors influence memory performance and the formation of false associations, with emotion being one of the most significant. Our findings confirmed that emotionally charged stimuli are remembered more effectively than neutral visual stimuli. Specifically, individuals recalled positively charged stimuli more accurately and consistently. Several explanations may account for these findings, ranging from the basic brain function to the achievement of psychological homeostasis and the innate human tendency to maintain a positive outlook on life. Particular emphasis is placed on the social context as a key factor in interpreting the results of this study. The current era, characterized by heightened stress and an overload of negative information, fosters a greater inclination to pursue positive emotionality, inner peace, and overall well-being. This pursuit enhances an individual's ability to concentrate, maintain attention and, importantly, improve memory retention. This study contributes to a deeper understanding of how the emotional charge of different stimuli can affect cognitive abilities and memory performance. Considering the significant role of memory in a variety of everyday settings, such as the workplace and education, this research also offers practical applications. However, it is important to note that exposure to positive content can lead to improvements in life circumstances. Such changes can, in turn, result in reduced stress, enhanced well-being, improved focus, and better overall memorization. The results suggest that memory and learning outcomes can be improved by integrating positively charged emotional value into the information being processed. Furthermore, this study may serve as a foundation for future scientific research and provide a valuable basis for investigating cross-cultural differences in the impact of emotional content on memory.

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The study was conducted in compliance with the ethical standards set by the Declaration of Helsinki (1964), and informed consent was provided to all participants.

The authors did not preregister their analysis plan.

Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, D.J. and Z.R.; methodology, D.J.; software, D.J.; formal analysis, D.J. and Z.R.; writing—original draft preparation, D.J.; writing—review and editing, D.J., Z.R. and P.S. All authors have read and agreed to the published version of the manuscript.

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Exploring Wikipedia Usage in Primary School Education: Students' Experiences and Perspectives

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Abstract: The rapid development of digital technologies and the accessibility of numerous online resources have significantly influenced contemporary education. Among these digital platforms, Wikipedia stands out as a widely visited and influential open-access online encyclopedia. While numerous studies have explored the use of Wikipedia in higher education, its potential in primary education remains underexamined. The purpose of this study is to investigate the opportunities for using Wikipedia in primary school education and to examine students' attitudes toward its use. The research was conducted on a sample of 364 seventh- and eighth-grade primary school students. A questionnaire was designed to assess students' opinions on the application of Wikipedia in educational contexts. Students were divided into two groups: one group used Wikipedia for lesson processing, while the other followed a traditional approach. Using the multivariate Kruskal-Wallis test and descriptive statistics, the results revealed that students hold slightly positive views on the use of Wikipedia in education, regardless of gender, grade level, academic performance, or prior classroom use of Wikipedia. Furthermore, the findings indicate that students in higher grades have experience using Wikipedia, though they generally lack formal exposure to it in classroom settings. Despite this, students frequently use Wikipedia for verifying information and completing homework, demonstrating openness to its integration into the educational process. This study highlights the potential for enhancing teaching practices in primary education by incorporating widely used digital information sources like Wikipedia.

Keywords: *Wikipedia in education, primary school education, students' attitudes, modernization of teaching.*

Introduction

Wikipedia is the largest and most widely used online encyclopedia, providing a multilingual platform for the collaborative creation and dissemination of knowledge. Due to its global openness and free access, Wikipedia is often considered an inclusive and democratic educational resource. As one of the most visited websites worldwide (Similarweb, 2025), it consistently ranks among the top search results, making it a highly accessible and influential information source (McDowell and Vetter, 2021). Wikipedia has become a global repository of human knowledge, offering an ever-expanding digital archive across diverse disciplines. While its scope and accessibility are undeniable strengths, they also give rise to certain challenges and criticisms, particularly regarding the reliability and quality of its content.

Despite its widespread use, Wikipedia has faced persistent criticism from the research and education communities, primarily due to concerns about the open-editing model, where anyone—including anonymous non-experts—can contribute. This often raises questions about academic credibility, as the absence of a formal peer-review process can lead to inconsistent quality, incomplete articles, and the occasional spread of misinformation. This open-access approach results in articles of varying quality, with some entries remaining incomplete, unsourced, or vulnerable to vandalism. The absence of a formal peer-review mechanism further exacerbates these issues, making it difficult to ensure the consistency and

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accuracy of the information presented (Christensen, 2015; Reinsalu et al., 2023). Teachers often express apprehension that students use Wikipedia as a primary source without critically evaluating its content or seeking alternative references (García-Delgado Giménez and Pinto Tortosa, 2024). Both teachers and students exhibit a lack of trust and a critical stance toward the platform. However, some initiatives have demonstrated the potential for improving the trustworthiness of Wikipedia through targeted educational interventions. For example, a study by Dudić et al. (2024) highlights efforts by Wikimedia Serbia to promote digital literacy and proper referencing among students, showing a significant improvement in students' understanding of trust mechanisms and responsible content creation on the platform. Moreover, research suggests that trust in Wikipedia varies depending on the level of education (Mothe and Sahut, 2018). Additionally, the platform has been criticized for systemic biases and imbalanced coverage, particularly in underrepresented sociocultural topics, which questions its aspiration to be a truly comprehensive and impartial repository of human knowledge.

Despite the criticisms surrounding Wikipedia's open-editing model, numerous studies highlight its significant pedagogical potential when integrated thoughtfully into the educational process. Wikipedia can serve as a powerful teaching tool by fostering active learning, enhancing student engagement, and promoting collaboration within study groups. Its application in the classroom supports the development of academic literacy (Azar, 2023; Bröcher et al., 2023; Evenstein Sigalov et al., 2024), as students improve their information retrieval and critical reading skills while participating in collaborative content creation. Moreover, Wikipedia-based assignments offer an authentic learning experience, allowing students to contribute to a global knowledge base while refining their research and writing abilities. This approach demands a purposeful integration by educators, ensuring that students not only consume information but also engage with it critically and responsibly.

In addition to Wikipedia, several sister projects (Commons, MediaWiki, Wikibooks, Wikidata, Wikiquote, Wikispecies, Wikiversity, Wiktionary, etc.) within the Wikimedia movement demonstrate significant potential for academic use. Among the most prominent is Wikidata, a free, multilingual, and open knowledge base that stores structured, linked data. For example, Wikidata, the largest semantic knowledge base in existence, offers unique learning opportunities (Evenstein Sigalov and Nachmias, 2023). Local initiatives also play an important role; for instance, the Wiki-librarian project (supported by Wikimedia Serbia) aims at training librarians and students of librarianship and information science to work with Wikipedia and other Wikimedia tools, enhancing digital literacy and contributing to the quality and expansion of Serbian Wikipedia's content (Stakić et al., 2021b). Similarly, the Professional Development of Teachers project (Ratković and Rudinac, 2023) focuses on equipping teachers from provincial areas with the skills needed to implement Wiki-projects in their schools, thereby promoting equity in access to open knowledge and fostering critical engagement with online information.

In order to better understand the educational potential of Wikipedia, it is important to consider relevant studies and initiatives from both Serbia and other countries. Comprehensive details on educational initiatives in Serbia are available at (Wikimedia Education - Serbia, n.d.). The following paragraphs provide an overview of significant projects and research conducted at different educational levels—higher, secondary, and primary education—which set the foundation for our study.

Regarding the integration of Wikipedia into higher education, the Wikipedia Education Program represents a global effort to incorporate Wikipedia into university classrooms. Davis et al. (2023) demonstrate its positive impact through case studies from Serbia, Israel, the United States/Canada, and Brazil, illustrating how Wikipedia-based activities can enhance student engagement and foster interdisciplinary collaboration. In Serbia, the Wiki Student project aims to integrate Wikipedia into higher education by engaging students in writing term papers on topics related to their university courses. Findings from this project indicate that faculty students generally hold positive attitudes toward Wikipedia's use in education, as shown in the study by Stakić et al. (2021a), which highlights its potential to innovate and enrich the learning process. Globally, numerous studies highlight Wikipedia's educational potential in higher education including Petrucco (2018), Zou et al. (2020), Cardoso and Pestana (2020), Malik et al. (2023), Sunvy and Reza (2023), Arslan and Turk (2024), Evenstein Sigalov et al. (2024), and many others.

Concerning high school education, Wikipedia has also proven to be a valuable educational tool with significant learning potential, as confirmed by numerous studies, such as Blikstad-Balas (2016) and Reinsalu et al. (2023). In Serbia, the Wiki Gymnasium project is specifically designed for high school students and teachers, aiming to familiarize them with Wikipedia's significance, benefits, and editing process. The

project encourages teachers to integrate Wikipedia into their teaching by assigning students to write term papers on subjects such as geography, history, and biology. Moreover, research conducted within these workshops has provided valuable insights into the educational potential of Wikipedia (Dudić et al., 2024).

There is also potential for integrating Wikipedia into primary education. A notable example is the Txikipedia project, a sub-project of the Basque Wikipedia aimed at children aged 8 to 13, offering simplified content primarily focused on mathematics and natural sciences. The study by Iribas Pardo et al. (2022) examined the appropriateness of mathematical content created for Txikipedia, showing that primary school students benefit from reading its textual and audiovisual materials, highlighting the role of digital humanities in enhancing mathematics education. In Serbia, the Wiki Schooler project serves as an initiative for introducing Wikipedia to primary school students and their teachers. The project has been implemented in several schools over the years, involving activities such as writing and editing Wikipedia pages on age-appropriate topics. However, compared to Wiki Student and Wiki Gymnasium, the engagement with Wikipedia at the primary school level has been more limited, both in terms of the number of participating institutions and the volume of content produced.

Since the use of Wikipedia in primary education has been the least explored, this study focuses specifically on examining its potential in that context. The research is conducted among 7th and 8th-grade students, aiming to determine how often they use Wikipedia and whether they recognize its educational potential. We explore whether students have previously used Wikipedia in their classes, for homework assignments, and for verifying information, assessing their perceptions of its applicability in the learning process.

Materials and Methods

Participants

The sample consisted of 364 students from Radoje Domanović Primary School and Vuk Karadžić Primary School in Vranje, Serbia, including 103 seventh-grade students and 261 eighth-grade students. It is important to note that the primary education system in Serbia consists of preschool education and eight years of primary school, meaning that the participants were in the final two grades of primary school. Students typically enroll in primary school between the ages of 6.5 and 7.5 years, so the participants in this study were approximately 14 to 15 years old.

The sample included students who attended either Civic Education or English Language classes. The students were divided into two groups. The first group of 214 students studied the lessons for the mentioned subjects in a traditional manner according to the curriculum. This group could have been surveyed at a random point during the study, independent of the lessons, but they were surveyed immediately at the beginning.

The second group of 150 students used Wikipedia as part of their lessons for the mentioned subjects, specifically during one class session. For example, students were allowed to consult Wikipedia during discussions to find answers, verify facts, etc. No prior training was provided on using Wikipedia; students used it as they were already familiar with it. During one of the following regular classes, these students filled out a questionnaire. Finally, the obtained data were statistically processed.

Research Design and Instruments

The research was conducted during February 2024, which corresponds to the beginning of the second term in the Serbian primary school system. The questionnaire was designed to evaluate the extent to which students use Wikipedia, whether they use it as part of their learning process, and to examine their attitudes toward using Wikipedia in primary school classrooms.

The data collection was conducted using the survey method, with an anonymous questionnaire as the primary instrument. This questionnaire was specifically developed for the purposes of this study and included items addressing all three research hypotheses. Participants' attitudes were measured using a five-point Likert scale, ranging from "completely disagree" to "completely agree". The questions aimed to assess students' familiarity with Wikipedia, their use of it in the learning process, and their perspectives on integrating Wikipedia into classroom activities in primary schools. Quantitative data obtained through the rating scale were processed using the SPSS statistical software. The analysis of the results employed

descriptive statistics, the multivariate Kruskal-Wallis test (MKW), and the Wilcoxon signed-rank test. The research findings are presented both in textual form and through tables.

Research Aims and Research Hypotheses

The aim of this research was to explore students' attitudes towards the use of Wikipedia in their learning process, both as a source of information and as an educational tool. The specific objectives of the study were:

1. To explore students' attitudes toward using Wikipedia in the classroom and examine whether these attitudes show statistically significant differences based on independent variables such as gender, grade level, and grade point average.
2. To determine whether students in higher grades of primary school use Wikipedia.
3. To examine whether students have prior experience with using Wikipedia in formal educational settings.

The General Hypothesis of the study posited that students have a positive attitude towards the use of Wikipedia in the learning process, both as an information source and as a teaching aid. Specific hypotheses:

H1: Students are open to the use of Wikipedia as part of classroom instruction and there are no significant differences in students' attitudes towards Wikipedia based on independent variables such as gender, grade level, or grade point average.

H2: Students in the higher grades of primary school have experience using Wikipedia.

H3: Students do not have prior experience with using Wikipedia in formal teaching.

Research Variables

The structure of the research required categorizing the variables into independent and dependent ones. The independent variables in this study were gender, grade level, grade point average and integration of Wikipedia into the educational process.

"Gender" refers to the potential differences in attitudes towards the use of Wikipedia between male and female students. Research consistently highlights a significant gender gap in Wikipedia engagement. For instance, a study on the Spanish Wikipedia revealed that only 11.6% of editors are women, with men outnumbering women by at least a 3:1 ratio across all Wikipedia sections (Minguillón et al., 2021). Additionally, global research on Wikipedia readership shows that women are underrepresented among readers, viewing fewer pages per session compared to men (Johnson et al., 2021). This trend is also reflected in local studies on the Serbian Wikipedia, which show similar gender disparities (Maljković, 2015). These findings suggest the importance of examining gender differences in students' attitudes towards Wikipedia's educational use.

"Grade level" is used to explore differences in attitudes between 7th- and 8th-grade students. As students progress through the final years of primary education, their familiarity with online resources and digital tools typically increases. Dúo-Terrón et al. (2022) similarly found that students' engagement and motivation toward information and communication technology (ICT) were influenced by their age and grade level, with sixth-grade students showing medium-to-high levels of ICT use. This suggests that grade level may play a significant role in shaping students' attitudes toward digital resources like Wikipedia.

"Grade point average" serves to assess whether students with higher academic performance are more inclined to view Wikipedia as a valuable tool in the learning process. This variable aims to determine whether students with better grades are more likely to embrace Wikipedia's inclusion in classroom instruction. The sample is divided into four groups based on students' previous year performance: 2.00–2.49 (sufficient), 2.50–3.49 (good), 3.50–4.49 (very good), and 4.50–5.00 (excellent). This grading system is a standard in Serbia. In a previous study by Stakić et al. (2021a), it was shown that grade point average does not influence university students' positive attitudes toward the use of Wikipedia in teaching. On the other hand, the study by Pavlović et al. (2017) reported statistically significant differences in university students' responses regarding their motivations for using Wikipedia based on their grade point average. The discrepancy in these findings may be attributed to the specific methodologies and sample characteristics of each study. Nevertheless, the importance of grade point average as a factor influencing students' attitudes toward educational tools remains evident, making it an important variable for further research, especially in the context of primary school education.

"Wikipedia integration": This variable distinguishes between two groups of students based on their exposure to Wikipedia during classroom instruction. The first group followed traditional teaching methods without the use of Wikipedia, while the second group incorporated Wikipedia into their lessons, using it to consult information, verify facts, and participate in discussions. This variable allows us to observe whether the integration of Wikipedia as a learning tool influences students' attitudes and perceptions.

The dependent variable in this study was the students' attitudes towards the integration of Wikipedia into the educational process. The research focused on analyzing the relationship between these independent variables (gender, grade level, and grade point average) and the dependent variable, i.e., students' attitudes towards the use of Wikipedia in teaching.

Results

The research results are presented separately, organized according to the proposed hypotheses. The presentation begins with the most significant hypothesis.

Hypothesis 1

Hypothesis H1 examines students' openness to the use of Wikipedia as part of classroom instruction. To test this hypothesis, we used the following statements:

Statement 1.1: *I eagerly use Wikipedia content for learning*.
Statement 1.2: *I think lessons would be more interesting if they were conducted with the help of Wikipedia.*
Statement 1.3: *I believe that textbook content should be supplemented with information from Wikipedia.*
Statement 1.4: *I believe that Wikipedia cannot be adequately used for teaching and learning purposes.* (*Reverse-coded*)

To test this hypothesis, we used the MKW version proposed by Katz and McSweeney (1980). There are two reasons why this test is suitable for hypothesis testing. First, it allows control over the alpha risk of the study, i.e., the risk of making an incorrect conclusion by rejecting the null hypothesis H_0 when it is true. Additionally, individual tests tend to overlook the interaction effects of different treatment factors. The results are presented in Table 1. MKW Results for All Factors Combined and Individually. Overall, the results indicate no statistically significant differences in students' responses to the four statements across the given factors (gender, grade level, academic performance and integration of Wikipedia into the educational process). Even when the MKW test is applied separately for each factor, no statistically significant differences are observed (all p-values are greater than 0.05, supporting the null hypothesis H_0 that there are no differences in responses). In other words, students' attitudes remain consistent regardless of gender, grade level, academic performance, or whether they used Wikipedia in classroom.

The variable of average grade shows a slightly lower p-value (0.081857) compared to the others, though it still does not reach the threshold for statistical significance ($p < 0.05$). This suggests a potential but not confirmed trend where students' academic performance may slightly influence their attitudes toward Wikipedia's use in learning, but more investigation would be required to establish a clearer relationship.

Table 1. *MKW Results for All Factors Combined and Individually*

Grouping variable	MKW Statistic	Number of groups (k)	p-value
All	101.9408	32	0.14695
Gender	2.474488	2	0.64921
Grade level	4.653141	2	0.324773
Average grade	19.28598	4	0.081857
Wikipedia integration	3.483216	2	0.480435

Despite the lack of statistical significance for variable "Wikipedia integration", students appear to have slightly positive views on the use of Wikipedia in education (Table 2. Distribution of Responses to Statements Assessing Students' Openness Towards Using Wikipedia in Classroom Instruction presents the distribution of responses). For instance, 52% of students either "Agree" or "Completely agree" with Statement 1.1 ("I eagerly use Wikipedia content for learning"), indicating a general willingness to incorpo-

rate Wikipedia into their study practices. The median response of 4 and the mode of 4 reinforce this positive trend. Statement 1.2 ("I think lessons would be more interesting if they were conducted with the help of Wikipedia") received a more mixed response, with 45.1% of students agreeing or completely agreeing. The median and mode responses of 3 suggest a more neutral attitude overall, yet a considerable portion of students still see potential for enhancing lesson engagement through Wikipedia. A similar pattern emerges with Statement 1.3 ("I believe that textbook content should be supplemented with information from Wikipedia"), where 44.5% of students expressed agreement. The median and mode of 3 again reflect a balance of opinions, suggesting that while many students see value in Wikipedia as a supplementary resource, there remains some hesitation. The reverse-coded Statement 1.4 ("I believe that Wikipedia cannot be adequately used for teaching and learning purposes") reveals a more cautious perspective on Wikipedia's reliability. Here, 42% of students either "Disagree" or "Completely disagree", indicating a notable portion of students who believe Wikipedia can indeed serve as a useful educational tool.

Table 2. *Distribution of Responses to Statements Assessing Students' Openness Towards Using Wikipedia in Classroom Instruction*

Statements		Completely disagree	Disagree	Neither agree nor disagree	Agree	Completely agree	Average	Median	Mode
I eagerly use Wikipedia content for learning	N	28	47	100	104	85	3.47	4	4
	%	7.7	12.9	27.5	28.6	23.4			
I think lessons would be more interesting if they were conducted with the help of Wikipedia	N	23	57	120	96	68	3.35	3	3
	%	6.3	15.7	33	26.4	18.7			
I believe that textbook content should be supplemented with information from Wikipedia	N	28	54	120	90	72	3.34	3	3
	%	7.7	14.8	33	24.7	19.8			
I believe that Wikipedia cannot be adequately used for teaching and learning purposes	N	58	95	132	65	14	2.68	3	3
	%	15.9	26.1	36.3	17.9	3.9			

Hypothesis 2

Hypothesis H2 states that students in the higher grades of primary school have experience using Wikipedia. This hypothesis was tested through four statements designed to capture students' frequency and purpose of Wikipedia usage:

Statement 2.1: *I frequently use Wikipedia.*

Statement 2.2: *I mostly use Wikipedia to verify various data.*

Statement 2.3: *I use Wikipedia as the main source of information whenever I encounter an unfamiliar term.*

Statement 2.4: *I do not use Wikipedia or use it very rarely.* (*Reverse-coded*)

The first statement was selected as the primary indicator for testing this hypothesis. A Wilcoxon signed-rank test was conducted to determine whether the median response was greater than 3 (H_0: Me ≤ 3). This test distinguishes between neutral or negative attitudes and positive attitudes toward frequent Wikipedia usage. The results are presented in Table 3 . Results of the Wilcoxon Signed-Rank Test for Frequent Wikipedia Usage yielding a Wilcoxon statistic of 22520, a median of 4, a p-value of 0.000, and a Cohen's r of 0.2993. As the null hypothesis was rejected, we can assert that the population median is greater than 3, indicating that students frequently use Wikipedia.

Table 3 . *Results of the Wilcoxon Signed-Rank Test for Frequent Wikipedia Usage*

Statement	Wilcoxon	Median	p-value	Cohen r
I frequently use Wikipedia	22520	4	0	0.2993

The Wilcoxon signed-rank test is a non-parametric test used to compare the median of a sample to an expected value—in this case, whether the median response is greater than 3. The Wilcoxon statistic (22520) is the calculated value of the test, which helps derive the p-value. The median response of 4 indicates that most students provided answers above the neutral value of 3, suggesting a positive attitude toward frequent Wikipedia use. The p-value of 0.000 (interpreted as <0.001) demonstrates a very low probability that this result occurred by chance, leading to the rejection of the null hypothesis and supporting the claim that students frequently use Wikipedia. Cohen's r of 0.2993 measures the effect size, showing a moderate strength of this positive tendency toward Wikipedia usage.

The descriptive statistics of all four statements provide additional insight into students' experiences with Wikipedia (see Table 4. Distribution of Responses to Statements Assessing Students' Experience with Wikipedia Usage for details). For Statement 2.1, 52.5% of students agreed or completely agreed that they frequently use Wikipedia, with a median of 4 and a mode of 4. This suggests a general tendency toward frequent usage. Statement 2.2 ("I mostly use Wikipedia to verify various data") received the most affirmative responses, with 80.2% of students agreeing or completely agreeing. The median response of 4 and a mode of 5 further emphasize the role of Wikipedia as a tool for data verification. Statement 2.3 ("I use Wikipedia as the main source of information whenever I encounter an unfamiliar term") also reflects a positive inclination, with 66.8% of students agreeing or completely agreeing. The median and mode responses of 4 and 5, respectively, suggest that a significant proportion of students rely on Wikipedia as their primary informational resource. In contrast, the reverse-coded Statement 2.4 ("I do not use Wikipedia or use it very rarely") shows a less favorable stance toward infrequent usage. Only 21.1% of students agreed or completely agreed with this statement, whereas 48.9% disagreed or completely disagreed. The average score of 2.6 and a median and mode of 3 indicate a balanced perspective with a slight tendency toward disagreement. These findings collectively support the hypothesis that students in the higher grades of primary school have substantial experience using Wikipedia, both as a general informational resource and as a means of verifying data.

Table 4. *Distribution of Responses to Statements Assessing Students' Experience with Wikipedia Usage*

Statements		Completely disagree	Disagree	Neither agree nor disagree	Agree	Completely agree	Average	Median	Mode
I frequently use Wikipedia	N	16	32	125	144	47	3.48	4	4
	%	4.4	8.8	34.3	39.6	12.9			
I mostly use Wikipedia to verify various data	N	13	19	40	134	158	4.11	4	5
	%	3.6	5.2	11	36.8	43.4			
I use Wikipedia as the main source of information whenever I encounter an unfamiliar term	N	16	18	87	107	136	3.9	4	5
	%	4.4	4.9	23.9	29.4	37.4			
I do not use Wikipedia or use it very rarely	N	75	103	109	46	31	2.6	3	3
	%	20.6	28.3	29.9	12.6	8.5			

Hypothesis 3

Hypothesis H3 states that students do not have prior experience with using Wikipedia in formal teaching. This hypothesis was tested through four statements designed to capture students' experiences and opportunities for using Wikipedia in educational contexts:

Statement 3.1: *I often find myself in a situation where we discuss Wikipedia content in class*.

Statement 3.2: *Teachers have directed us to Wikipedia as a source of information for learning*.

Statement 3.3: *I frequently use Wikipedia as an additional source of information when doing homework or other tasks.*

Statement 3.4: *I have not had the opportunity to use Wikipedia for teaching and learning purposes*.

The first statement was selected as the primary indicator for testing this hypothesis. Again, the Wilcoxon signed-rank test was conducted to determine whether the median response was greater than 3 (H_0: Me ≤ 3). Analogously, the test distinguishes between neutral or negative attitudes and positive at-

titudes toward discussing Wikipedia content in class. The results are presented in Table 5. Results of the Wilcoxon Signed-Rank Test for Students' Discussion of Wikipedia Content in Class, yielding a Wilcoxon statistic of 7239, a median of 2, a p-value of 1, and no calculable Cohen's r.

Table 5. *Results of the Wilcoxon Signed-Rank Test for Students' Discussion of Wikipedia Content in Class*

Statement	Wilcoxon	Median	p-value	Cohen r
I often find myself in a situation where we discuss Wikipedia content in class	7239	2	1	-

The median response of 2 indicates that most students provided answers below the neutral value of 3, suggesting a lack of classroom discussions involving Wikipedia content. The p-value of 1 suggests no statistical significance, leading to the acceptance of the null hypothesis and supporting the claim that students generally do not discuss Wikipedia content in class.

The descriptive statistics of all four statements provide additional insight into students' experiences with Wikipedia in formal teaching. Table 6. Distribution of Responses to Statements Assessing Students' Experience with Wikipedia in Formal Education presents the distribution of responses for all four statements assessing students' experiences with Wikipedia in formal teaching. For Statement 3.1 ("I often find myself in a situation where we discuss Wikipedia content in class"), the majority of students expressed disagreement, with 33% completely disagreeing and 25.8% disagreeing. The median response of 2 and mode of 1 confirm the rarity of such discussions. Statement 3.2 ("Teachers have directed us to Wikipedia as a source of information for learning") received a more balanced set of responses, with 22.5% agreeing and 11% completely agreeing, while 20% completely disagreed. The median and mode responses of 3 reflect a neutral stance.

In contrast, Statement 3.3 ("I frequently use Wikipedia as an additional source of information when doing homework or other tasks") shows a more positive tendency, with 35.2% agreeing and 22.5% completely agreeing. The median and mode of 4 suggest that students often turn to Wikipedia for individual learning purposes. Finally, the reverse-coded Statement 3.4 ("I have not had the opportunity to use Wikipedia for teaching and learning purposes") aligns with the hypothesis, as 30.5% completely disagreed and 26.9% disagreed. The median and mode of 2 indicate that many students acknowledge some opportunities for using Wikipedia, albeit infrequently. These findings collectively support the hypothesis that students generally lack formal classroom experience with Wikipedia, though they frequently use it for individual learning and homework support.

Table 6. *Distribution of Responses to Statements Assessing Students' Experience with Wikipedia in Formal Education*

Statements		Completely disagree	Disagree	Neither agree nor disagree	Agree	Completely agree	Average	Median	Mode
I often find myself in a situation where we discuss Wikipedia content in class	N	120	94	84	48	18	2.31	2	1
	%	33	25.8	23.1	13.2	4.9			
Teachers have directed us to Wikipedia as a source of information for learning	N	73	75	94	82	40	2.95	3	3
	%	20	20.6	25.8	22.5	11			
I frequently use Wikipedia as an additional source of information when doing homework or other tasks	N	20	51	83	128	82	3.55	4	4
	%	5.5	14	22.8	35.2	22.5			
I have not had the opportunity to use Wikipedia for teaching and learning purposes	N	111	98	96	41	18	2.33	2	1
	%	30.5	26.9	26.4	11.3	4.9			

Discussions

The results obtained from this research cannot be generalized, as the sample size could have been larger and more representative. Additionally, the study was conducted in Vranje, a small town in southern Serbia, one of the country's least developed regions, and the socio-economic background of the participants was not considered in this research. These factors may influence the attitudes and experiences of students, suggesting the need for broader, more diverse sampling in future studies.

The results of testing H1 indicate that students' attitudes remain consistent regardless of gender, grade level, academic performance, or whether they used Wikipedia in classroom instruction. The absence of differences in attitudes based on gender, grade level, average grade, or previous exposure to Wikipedia-based lessons can be interpreted in several ways. Although previous studies with university students have shown mixed findings—some indicating gender-based differences (Remmik et al., 2024) and others not (Stakić et al., 2021a)—no such differences were observed in this study. Similarly, there were no differences in attitudes based on grade level. Given that the participants were 7th and 8th-grade students, their closeness in age likely contributes to the uniformity of their responses.

It is worth noting that the variable of average grade shows a slightly lower p-value (0.081857) compared to the others, though it still does not reach the threshold for statistical significance ($p < 0.05$). This suggests a potential but not yet confirmed trend where students' academic performance may slightly influence their attitudes toward Wikipedia's use in learning. Further investigation with larger and more diverse samples could help establish a clearer relationship, especially at higher levels of education.

An intriguing finding is the lack of change in students' attitudes despite their engagement with lessons where Wikipedia was used as a resource. This may be influenced by the choice of subjects—English and Civic Education—which may not be the most suitable for demonstrating Wikipedia's full educational potential. A subject-specific analysis would likely provide more nuanced insights. Additionally, only one lesson was covered in each subject, which may have been insufficient for students to fully experience Wikipedia's usefulness, especially if the lesson content did not require extensive use of the platform.

Moreover, students did not receive any formal training on how to use Wikipedia effectively. Training and contribution to Wikipedia could play a crucial role in shaping students' perceptions, as it would allow them to explore Wikipedia's possibilities and its potential for classroom learning more comprehensively (see Soler-Adillon, Pavlovic and Freixa, 2018). These factors likely contribute to the observed uniformity in attitudes.

On the other hand, these results open up multiple avenues for future research. Investigating how students' perceptions evolve with more extensive and subject-specific integration of Wikipedia, examining the impact of formal training, and exploring the role of socio-economic factors could provide a deeper understanding of Wikipedia's educational potential.

The results of testing H2 indicate that students in the higher grades of primary school have experience using Wikipedia. The high frequency of Wikipedia usage among students can be interpreted in several ways. First, it aligns with global trends indicating that Wikipedia is one of the most widely used online knowledge resources. Students' reliance on Wikipedia for verifying data and understanding unfamiliar terms highlights the platform's perceived credibility and accessibility. This suggests that Wikipedia has already established itself as an essential part of students' informal learning practices, even when not directly integrated into classroom instruction. However, the results also open up questions about the depth and quality of students' engagement with Wikipedia. While the frequency of use is evident, it remains unclear how critically students approach the information they find there or whether they cross-reference it with other sources. Future research could explore students' information literacy skills and their ability to evaluate the reliability of Wikipedia content.

Moreover, the reverse-coded statement (Statement 2.4) indicating rare or no Wikipedia use received low agreement, further reinforcing the overall positive attitude toward the platform. This consistency across multiple indicators strengthens the conclusion that Wikipedia is already a familiar and frequently used tool among primary school students, making it a promising resource for more structured educational integration.

The results of testing H3, indicate that students generally lack formal classroom experience with Wikipedia. Discussions involving Wikipedia content are rare in classroom settings. Descriptive statistics further reinforce this, as the majority of students expressed disagreement with statements about using

Wikipedia as a teaching resource. However, the data also reveal an interesting contrast: while Wikipedia is rarely incorporated into formal instruction, students frequently use it as an additional source for homework and independent learning, which is consistent with findings by Blikstad-Balas (2016). The positive responses to Statement 3.3 highlight this tendency, suggesting that students recognize Wikipedia's value and reliability outside the classroom context. This discrepancy points to a clear gap between students' informal learning habits and classroom practices. It suggests an opportunity for educators to better integrate Wikipedia into teaching strategies, aligning instruction with students' existing digital literacy practices. Greater teacher involvement and structured guidance on using Wikipedia could enhance its educational potential and foster more critical engagement with online information sources.

Conclusions

This study explored the attitudes and experiences of 7th- and 8th-grade primary school students toward the use of Wikipedia in education. The results showed that students generally hold slightly positive views on Wikipedia's educational use, regardless of gender, grade level, academic performance, or whether they have used Wikipedia as part of classroom instruction. While students frequently use Wikipedia for verifying information and completing homework, their formal exposure to it in classroom settings remains limited. These findings highlight an opportunity to better align teaching practices with students' existing learning habits by integrating widely used digital resources like Wikipedia. Moreover, the results are encouraging for initiatives such as the Wiki Schooler project, suggesting that structured efforts to introduce Wikipedia into primary education could resonate well with students' existing digital behaviors. By formalizing Wikipedia-based activities in the classroom, educators may enhance students' information literacy and critical thinking skills from an early age.

Furthermore, these findings align with previous research on Wikipedia's role in education, particularly in secondary and higher education. However, this study expands on existing literature by focusing on primary school students—an area that remains relatively underexplored. Given the growing importance of digital resources in early education, future research could further investigate the subject-specific benefits of Wikipedia integration, as well as the role of teacher training in maximizing its educational potential.

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Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, M.S., M.T. and Đ.S.; methodology, M.S., M.T., Đ.S. and A.D.; software, A.D.; formal analysis, M.S., M.T., Đ.S. and A.D.; writing—original draft preparation, M.S.; writing—review and editing, M.S., M.T. and Đ.S.; supervision, M.S. All authors have read and agreed to the published version of the manuscript.

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Fostering Metacognitive Skills and Learning Motivation Through Hybrid Learning with Innovative Learning Strategies

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Abstract: The integration of technology into instruction is essential to address teachers' challenges in delivering biology content with greater clarity and depth. This process can be effectively guided by Technology, Pedagogy, and Knowledge Content (TPACK) framework. Grounded in this framework, this study aims to develop valid, practical, and effective hybrid learning resources for biology classes, specifically in the form of lesson plans, assessment tools, and Moodle-based e-learning materials. To achieve this, this study designed and implemented a GITTW strategy that combines Group Investigation (GI) and Think Talk Write (TTW) strategies. This study employed a Research and Development (R&D) methodology using the Four-D model: Define, Design, Develop, and Disseminate. A total of 80 tenth-grade students from Muhammadiyah 3 Senior High School at Surabaya, Indonesia participated in the study. Prior to implementation, the GITTW underwent validation and was deemed valid. Its practicality was supported by data from a student learning independence. This study found that the GITTW lesson plans, assessment forms, and Moodle-based e-learning materials were valid, practical, and effective in enhancing students' metacognitive skills and learning motivation. These results confirm the feasibility of integrating the GITTW strategy into Moodle for biology education to support the development of students' metacognitive skills and motivation. Further studies could explore the integration of GITTW with augmented reality (AR) to facilitate a more in-depth exploration of biology content.

Keywords: *metacognitive skills, learning motivation, hybrid learning, innovative learning.*

Introduction

The rapid development of 21st-century technology has had a profound impact on the field of education, making the integration of technology into learning not only beneficial but essential. One widely recognized framework that supports this integration is Technological Pedagogical Content Knowledge (TPACK), which highlights the interplay among technology, pedagogy, and content in effective instructional design. A thorough understanding of the complex relationships among these three domains is critical for meaningful technology integration in the classroom (Tanak, 2020). The foundation for this integration was laid by NACOL (North American Council for Online Learning), which introduced a learning model that combines face-to-face (offline) instruction with online learning supported by web-based technology (e-learning). This model leverages internet-based platforms that enable students to access learning materials anytime and anywhere (Bahri et al., 2020; Sibley et al., 2024)

Hybrid learning is an emerging instructional approach that corresponds to the model proposed by NACOL. It integrates technology and internet-based to enhance student's learning experience while supporting teachers in improving their teaching methods (Türkmen, 2024). It combines face-to-face learning and electronic learning conducted simultaneously (Min and Yu, 2023; Sukiman et al., 2022). A key feature of this approach is strong student engagement, which serves as a prerequisite for effective learning out-

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comes (De Bruijn-Smolders and Prinsen, 2024). Teachers who implement this approach are also actively involved in course design and interaction with students, facilitating a more responsive and dynamic learning environment (Bozkurt, 2022; Raes, 2022).

The approach also places particular emphasis on the use of Learning Management Systems (LMS) to support and enhance teaching and learning processes (Gamage et al., 2022). LMS enables the delivery of learning content without requiring face-to-face interaction, using either intranet or internet networks (Shchedrina et al., 2021). The integration of LMS in hybrid learning is both feasible and has the potential to enhance student engagement, collaboration, and overall learning experiences. However, several factors must be considered to ensure successful implementation. According to Chiu (2021, 2022), teacher effectiveness and the availability of digital support are critical, as these elements significantly influence student engagement, which can vary across face-to-face and LMS-supported learning environments. Similarly, Mohd Mushtaq and Zahir Iqbal,(2024) highlight the critical role of technology infrastructure in supporting successful implementation. Addressing these factors, Busara Niyomves et al., (2024) argue that hybrid learning can offer the flexibility of online education while retaining the interpersonal benefits of in-person instruction, thereby meeting a wide range of learning needs and schedules.

Moodle is one of the widely used LMS that offers siginicant benefits for hybrid learning environment. It is a software package specifically designed to facilitate the development of internet-based programs and websites. According to Aikina and Bolsunovskaya, (2020), Peramunugamage et al., (2020), and Gamage et al., (2022), Moodle is an effective learning platform due to its interactive features, the integration of multimedia content, and the opportunities it offers for student collaboration. Additionally, Chang et al., (2022) highlight that Moodle supports the delivery of electronic materials, learning media, structured learning paths, and assessments, all of which contribute to increased learning efficiency. Goyal et al., (2023) further emphasize that the implementation of Moodle enhances the quality of learning, increases student interest, and boosts motivation, factors that positively influence learning outcomes. Similarly, recent scholarship by Raman et al., (2022), Gudkova et al., (2021) and Mustapha et al., (2023) indicate that the effective use of Moodle is strongly influenced by students' intrinsic motivation. In this regard, fostering student motivation in biology education is essential, as it plays a critical role in improving learning outcomes.

Biology instruction at the high school level involves the study of complex conceptual material related to processes in the human body, animals, plants, and various natural phenomena. Teachers often encounter challenges in delivering these concepts comprehensively due to limited instructional time. Typically, biology lessons are allocated only two meetings per week, consisting of two class hours (2x45 minutes) and one class hour (1x45 minutes) on separate days. Given the abstract and dynamic nature of biological processes, students require more than verbal explanations: these concepts must also be visualized using instructional media such as videos, diagrams, or interactive images. Furthermore, students are expected to be active and autonomous, capable of seeking additional information and solving problems using online resources. The implementation of hybrid learning through platforms such as Moodle offers a promising approach to address these challenges. It can enhance student motivation, foster active participation, and support self-regulated learning by allowing students to access learning materials flexibly and interactively beyond the constraints of classroom time.

The implementation of hybrid learning should be optimized through the integration of instructional models that actively support students in developing problem-solving skills. One such model is the Group Investigation integrated with the Think-Talk-write (GITTW) strategy, a cooperative learning approach whose syntax includes identifying topics, organizing groups, planning tasks, investigating, analyzing, presenting, and evaluating results, while integrating the "think, talk, and write" processes at each stage (Listiana, 2016 from Sharan and Sharan, 1992 and Huinker and Laughlin, 1996). Each phase of the GITTW strategy is designed to foster students' self-regulation by encouraging them to plan tasks and select appropriate learning strategies independently. Both the group Investigation (GI) and Think-Talk-Write (TTW) components emphasize collaboration, requiring students to work cooperatively in completing tasks. Moreover, this model encourages students to engage in self-assessment and self-monitoring, which are essential aspects of self-regulated learning.

Within the GI component of GITTW, students are guided to work collaboratively in groups. According to Mitchell et al., (2008), this stage involves formulating questions or identifying problems, as well as selecting appropriate procedures for monitoring and assessment. Tsoi et al., (2004) noted that the IG approach encourages students to take an active role in determining what and how they learn. In the final

stage of GI, students collaborate to draw conclusions, develop strategies for presenting their findings, and evaluate their group's performance. Meanwhile, in the TTW component of GITTW, the "think" stage is intended to strengthen students' critical thinking skills. This stage plays a crucial role as students identify problems, determine suitable strategies, and develop plans for problem-solving. The "talk" and "write" stages are reflected in students' presentations and group discussions of their solutions. Through these integrated activities, the GITTW strategy is expected to cultivate students' independent learning skills and promote deeper engagement in the learning process.

Previous studies have demonstrated the potential of the GITTW strategy to enhance students' metacognitive skills. For instance, Listiana, et al. (2016) reported that the GITTW approach significantly contributes to the development of metacognitive skills, while further research from Listiana et al. (2020) showed improvements in students' self-regulation, which in turn positively influenced their learning outcomes. Both GI and TTW components within the GITTW framework share a common goal: cultivating metacognitive awareness. This enables students to plan appropriate problem-solving strategies, regulate their learning process, and assess their own work effectively. Moreover, Listiana, et al. (2023) found that the six syntactical stages of the GITTW strategy effectively enhance students' critical thinking and collaboration skills.

In the context of hybrid learning, the development of metacognitive skills is essential, as students are required to plan, monitor, and control their learning processes to achieve optimal outcomes. Fayaza and Ahangama (2024) argue that in blended learning environments**,** self-directed learners are more likely to achieve improvements in cognitive, metacognitive, and motivational learning domains. Similarly, Essa, (2023) asserts that hybrid learning ha a strong positive correlation with the development of deep learning competencies. Acosta-Gonzaga and Ramirez-Arellano (2021) further emphasize the relationship between cognitive and metacognitive strategies and students' motivation in blended learning contexts. This is supported by Monika and Devi (2022) , who found that blended learning enhances student engagement, interaction, academic achievement, motivation, and the overall learning process.

Considering the challenges identified, students' limited understanding of biological processes in the human body, teachers' difficulties in delivering detailed explanations, and the underutilization of technology in biology instruction, it becomes crucial to integrate technological tools in meaningful ways. One potential solution involves the use of Moodle-based media within a hybrid learning model, supported by an innovative instructional strategy such as GITTW. Therefore, this study aims to develop a comprehensive instructional package, including lesson plans, student worksheets, evaluation tools, and Moodle-based e-learning media (accessible via https://tacticedu.com), that is valid, practical, and effective for teaching biology. Although previous studies have explored the use of Moodle in e-learning, this study adopts a distinct approach by integrating Moodle with the GITTW strategy, which is expected to promote students' metacognitive development and support their growth as independent learners.

Materials and Methods

This study employed a Research and Development (R & D) study, following the Four-D development model proposed by Thiagrajan (1974)**,** which consists of four stages: Define, Design, Develop, and Disseminate**.** The primary objective of this study is to produce instructional materials**,** including lesson plans, student worksheets, evaluation sheets, and moodle-based e-learning media (accessible by https://tacticedu.com), that are valid, practical, and effective for learning.

Sample and Data Collection

This study was conducted with 10th-grade students at SMA Muhammadiyah 3 Surabaya**.** It employed a saturated sampling technique, involving the entire population of Grade 10 students, consisting of 80 active learners enrolled in the biology subject. This sampling method was chosen based on the relatively small number of students in Grade 10, making it feasible to include all participants. The study implemented a hybrid learning model integrated with the GITTW strategy, using Moodle-based media, adhering to the structured learning syntax designed for this model. The biology topics covered included virus structure, replication processes, and the role of viruses in life.

Research Instrument Validity, and Reliability

The instruments used were questionnaires, validation assessment sheets, product practicality evaluation sheets, and product effectiveness tests**.** The data collection techniques employed were: (1) The validity of the instructional materials, including lesson plans, student worksheets, evaluation tests, and Moodle-based media, was assessed using validation sheets by 3 experts. (2) The reliability of the instructional materials was tested using Cronbach's alpha, with the results interpreted based on the levels of reliability categorized as very high, high, moderate, or low. (3) Practicality data were collected through questionnaires to gather students' and teachers' responses regarding the use of Moodle-based e-learning. (4) The effectiveness of the product was evaluated using essay tests that incorporated indicators of metacognitive skills (Corebima, 2006)**.** (5) Data on students' learning motivation were obtained through a motivation questionnaire.

Research Procedure

The research procedure consisted of the following stages: (1) Define: This step included several steps: front-end analysis, task analysis, learner analysis, concept analysis, and learning objectives analysis. (2) Design**:** This step involved selecting instructional media, choosing the appropriate format, developing the product, and preparing instructional materials for face-to-face learning. It also included preparing e-learning media (Moodle) and designing the initial Moodle framework within a hybrid learning model integrated with the GITTW strategy. (3) Develop**:** This step focused on developing instructional materials and the Moodle platform within the hybrid learning model integrated with the GITTW strategy, which was validated by three experts (validators). This was followed by product testing to evaluate the quality of the Moodle-based hybrid learning model for biology subjects, and (4) Disseminate**:** This final step involved large-scale experimental implementation, which is planned for the subsequent academic year.

Analyzing of Data

The data analysis technique employed both inferential and descriptive statistical analyses. The analyses were carried out as follows: (1) feasibility validation was conducted through scoring, followed by percentage calculation, and then categorized according to validity levels based on Hobri (2009), as follows: strongly valid (4.6 to 5), valid (3.6 to 4.5), less valid (2.6 to 3.5), invalid (1.6 to 2.5) and strongly invalid (less than 1.6). (2) The data related product practicality, Moodle-based e-learning, were gathered using questionnaire from student and teacher. The responses were analyzed quantitatively using percentage and categorized according to Arikunto (2002) as very practical (84%-100%), practical (68%-83%), quite practical (52%-67%), less practical (36%-51%), and impractical (less than 35%). (3) The effectiveness data were analyzed descriptively quantitatively using N-gain score based on (Hake, 199 C.E.), an N-gain score ≤ 0.30 indicates low improvement, 0.30 < N- gain ≤ 0.70 indicates moderate improvement, and 0.70 < N-gain ≤ 1.00 indicates high improvement. (4) Student learning motivation was measured using a questionnaire adapted from the ARCS (attention, relevance, confidence, and satisfaction) model of Keller (1987). The questionnaire used a Likert scale consisting of very agree, agree, disagree, and very disagree.

Results

This study developed a Hybrid Learning model integrated with GITTW strategy, comprising lesson plans, student worksheets, evaluation sheets, and GITTW-integrated Moodle-based e-learning media. The learning model involved a combination of e-learning and face-to-face learning. The educational media product (Moodle) produced was in the form of a website, taxticedu.com, and its implementation was based on the GITTW strategy syntax. The research development model was the 4D development model (Four-D Models).

A. Define Media Moodle

At the define stage, the analysis of tasks revealed that the assignments provided by teachers did not adequately support independent learning. Students had limited opportunities to explore information in depth, and the flexibility of tasks was minimal, resulting in constraints related to time and collation for

task completion. Furthermore, the methods for accessing tasks remained conventional, and the types of assignments lacked variation, particularly in addressing diverse student learning styles. In the context of blended learning, task design must prioritize accessibility, diversity, and flexibility. Through the integration of e-learning media, tasks can be differentiated to accommodate various learning preferences, enabling students to complete assignments anytime and anywhere without restrictions.

The student analysis considered gendered distribution and initial competencies related to the learning topic of viruses. Findings indicated that students' prior knowledge of the subject matter was insufficient, and foundational understanding was limited. Students exhibited a range of learning styles, visual, auditory, kinaesthetic, or mixed learning styles, which provided valuable insights for the design of instructional materials and media. Additionally, students' motivation and interest in learning were found to be low and in need of reinforcement. Another significant challenge was students' limited proficiency in using technological devices, which stemmed from the restricted availability of laptops, tables, or smartphones, along with limited access to the internet and e-learning platforms such as Moodle and Google Classroom.

The concept analysis revealed that the subject matter ranged in complexity from simple to advanced. However, no instructional modules or teaching materials were available that clearly structured and sequenced these concepts to build coherent understanding. Instructional delivery remained largely conventional with limited access to supplementary resources. Therefore, the development of interactive e-learning media is crucial. Media such as videos, infographics, animations, and simulations can enhance students' understanding and allow them to access complex content more independently and effectively.

Although the existing learning objectives encompassed cognitive, affective, and psychomotor domains, they did not clearly reflect the targeted competencies. Several objectives lacked alignment with instructional activities and media, resulting in weak learning outcomes. Thus, it is essential to develop e-learning media, particularly using Moodle, as a flexible and adaptive platform. This approach can accommodate diverse learning styles while enabling educators to present instructional content in a dynamic, interactive, and competency-oriented manner.

B. Design Media Moodle

The Moodle media developed based on several criteria is shown in Table 1.

Table 1. *Moodle development design*

	Development Design
Design Name	Hybrid Learning integrated with GITTW strategy
Sponsor	DRPM Grant
Needs	innovative learning media to enhance learning motivation and metacognitive skills
Reasoning	Most schools do not yet have Moodle-based e-learning media that supports hybrid learning.
Expected results	Hybrid learning integrated GITTW strategy with media moodle is valid, practical and effective.
Customer	Students who study in SMA Muhammadiyah grade X, Surabaya.
Design's aim	Producing valid, practical, and effective lesson plans, student worksheets, evaluation sheets, and Moodle-based e-learning as innovative learning media and resources that can enhance learning motivation.
Knowledge, skills and abilities of customer	Students have knowledge, skills, abilities in operating computers, laptops, and mobile phones, making it easy for them to adapt to the Moodle platform
Feedback	Students can be motivated to learn, becoming independent learners to construct knowledge. Helping teachers as a learning medium that supports hybrid learning
Benefits	The design produces innovative media and learning resources that facilitate students and teachers in hybrid learning.

The design format of the developed moodle e-learning consists of features presented in Table 2.

Table 2. *A design of moodle*

Component of e-learning	Sub Component of e-learning
Hompepage (log-in page)	Name of e-learning, log in of account, and information of e-learning
Main page (Dashboard)	Site home, calendar, course name, timeline, and upcoming events
Site home	Available course name
Course page	Participants, introduction, pre-test, content competence, basic competence, learning objectives, material content, forum discussion, student worksheet, quiz, and score

C. Development Moodle

Moodle and the accompanying instructional tools, including evaluation sheets and lesson plans, are products specifically developed to support hybrid learning. The outcomes of the Moodle-based hybrid learning model can be observed through several key components: (1) the front page (login page), (2) the main page (dashboard), and (3) the course page. In this hybrid-based learning environment, all sessions were conducted online for students who were unable to attend in person (outside the classroom), while face-to-face instruction was provided for those present in class. Moreover, the Moodle-platform offers a range of learning recourses, including condensed learning materials, instructional videos, and external resource links. Each session incorporated interactive features such as discussion forums, chat functions, assignments, quizzes, and attendance tracking. Assignments and assessments were designed to be completed within a specific time frame, encouraging student responsibility and time management. These features were strategically integrated to meet the pedagogical needs of both teachers and students throughout the teaching and learning process.

The Moodle platform, accessible view https://tacticedu.com, has been equipped with user manual tailored both for teachers and students. These guides are protected by copyright and serve as practical references to facilitate the effective use of the platform. Figure 1 shows the main interface of the developed Moodle system.

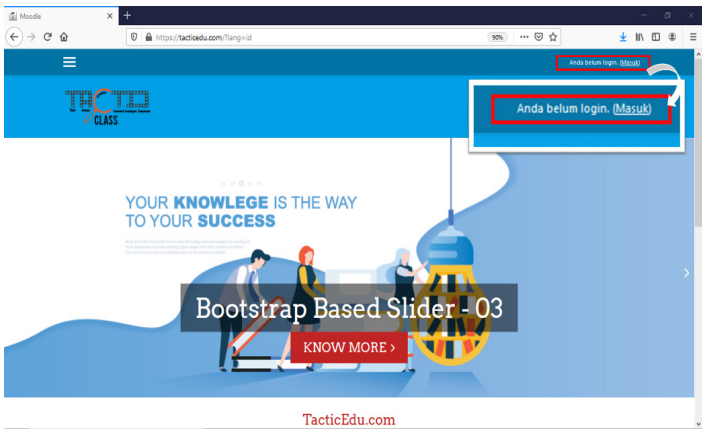

Figure 1. Front page view of moodle http://tacticedu.com

The developed product consisted of a Moodle-based learning and supporting e-learning resources. The resources included lesson plans, student worksheets, evaluation sheets, and validation instruments. The product was evaluated by three expert validators to ensure its quality and relevance. Validation was carried out through a comprehensive review of the developed components. This product was validated by three expert validators. Validation was conducted by reviewing the developed product. Furthermore, the validity of the Moodle-based learning platform and its associated learning recourses was assessed using the validators' evaluation, with the results presented in Table 3 through 8. The validation results for the lesson plan yielded an average score of 4.41 across several evaluation aspects. This score falls within the "valid" category, as shown in Table 3.

Table 3. *Result of the validation of the lesson plan*

Aspect	Average Scores	Category
The identity of lesson plan	5.00	Strongly valid
The time allocation	4.00	valid
Learning achievement competencies include attitudes, knowledge and skills	4.25	valid
Development of course material	4.33	valid
The alignment between the learning model used and the learning steps	4.00	valid
The method learning can used based on suitability with the characteristics of the objectives, situation, and conditions.	4.00	valid
Accuracy Learning steps	4.33	valid
The assessment is based on certain indicators and criteria	3.50	less valid
The Reference can used in the preparation of student worksheets and course material	4.50	valid

Table 3 shows that all aspects of the lesson plan were categorized as valid to highly valid, with exception of one aspect classified as “less valid”, namely “the assessment is based on certain indicators and criteria,” which received an average score of only 3.50. This finding is noteworthy, as it suggests that although the lesson planning was well-structured in terms of identity, content, and instructional methods, the assessment component remained a critical weakness. This may indicate the need for improvement in formulating evaluation indicators that are both appropriate and meaningful in relation to the learning objectives and the metacognitive skills aimed to be developed.

The results of the validation from three expert validators on the student worksheets yielded an average score of 4.06, which is classified as “moderately valid”, as presented in Table 4.

Table 4. *Results of the validation of student worksheet*

Aspect	Average Score	Category
Content: the alignment of basic competencies with core competencies, the alignment of indicators and learning objectives, the alignment of objectives with tasks	4.50	strong valid
Presentation: relevance of the topic to the material, coherence of the material, and supporting student assignments	4.00	valid
Language: A communicative, simple, and easy-to-understand language	4.00	valid
Display: accuracy of image layout, presentation clear and easy To understand	3.75	valid

Table 4 shows that the content aspect of the student worksheets received the highest score (4.50), falling into the “strongly valid” category. This indicates that the primary strength of the worksheets lies in the alignment between indicators, objectives, and learning activities with the core competencies. However, another notable finding concerned the display aspect, which received the lowest score (3.75) among all evaluated components. Although still categorized as “valid,” this suggests that visual elements, such as layout, image placement, and clarity of presentation, require further improvement. In the context of digital learning, effective visualization plays a crucial role in enhancing student engagement and comprehension.

The results of the Moodle validation by three media expert validators yielded an average score of 3.97 across several aspects, as presented in Table 5.

Table 5. *Moodle-based e-learning validity results*

Aspect	Average Score	Category
Layout Proportions (content area, header, and widget)	3.75	valid
Proposal Layout (text and image layout) from the material	3.50	less valid
The suitability of the header design and color proportions	4.00	valid
The suitability of font type and size selection	3.50	less valid
The appeal of the animation presentation, and the suitability of the animation with material	3.00	less valid
A simple and polite appearance (does not contain irrelevant images and objects)	4.00	valid
Ease of use of the program, navigation language and widgets in the program	5.00	strongly valid
Ease of interacting with the program and understanding the navigation structure	4.00	valid
Ease of *login* and *logout* from the program	5.00	strongly valid

Table 5 shows that the aspects of program usability and the login-logout process received a perfect score of 5.00 and were categorized as strongly valid, highlighting Moodle's strength in terms of technical accessibility. However, an interesting finding emerged in the aspect of animation and its relevance to the learning material, which received a score of only 3.00 and was categorized as less valid. This suggests that although Moodle is highly accessible, the quality of interactive visuals such as animations require improvement. Animation is a crucial element in biology instruction, particularly given the subject's inherently visual and procedural in nature.

The result of the course material validation by three expert validators, based on several aspects as presented in Table 6, yielded an average score of 4.3, which falls into the "valid" category.

Table 6. *Course material validation results*

Aspect	Average Score	Category
Scope: breadth and depth of content, structure and sequence content	4.75	valid
Clarity and the appeal of the material in aiding understanding.	4	valid
Clarity of instructions for solving practice questions, question formulation, and difficulty level	4.5	valid
Clarity of Language and information in image illustrations	4	valid

Table 6 shows that all aspects of the course material were categorized as valid, with the highest score recorded in content coverage (4.75). A noteworthy finding emerged from the fact that two aspects, the clarity and attractiveness of the material, as well as the clarity of language and image illustrations, received a lower score of 4. This indicates that although the content is comprehensive and well-structured, there remains room for improvement in visual and narrative presentation to enhance both aesthetic appeal and ease of understanding.

The result of the validation on the evaluation sheet, an integrated metacognitive skills test in the form of an essay questions, conducted by three expert validators yielded an average score of 3.91, which falls within the "valid" category. The scores based on various aspects are presented in Table 7.

Table 7. *Results of the evaluation sheet validation*

Aspect	Average Score	Category
Material Aspect: the alignment of cognitive aspects measured with basic competencies, the alignment of question items with learning objectives and cognitive aspects.	3.75	valid
Construction Aspects: clarity of instructions, assessment rubrics, and formulation of concise sentences	4.00	valid
Language Aspect: Question items with well-structured sentences, communicative sentences, easy to understand, and language that does not contain double meanings.	4.00	valid

Table 7 shows that all aspects of the evaluation sheet are categorized as valid, with the highest score (4.00) achieved in the aspects of construction and language. Another noteworthy finding is observed in the content aspect, which received the lowest score (3.75), although it still falls within the "valid" category. This finding is significant, as the primary objective of an evaluation is to ensure that the assessment accurately represents the competencies intended to be measured. If this alignment is lacking, the effectiveness of learning outcomes measurement may be compromised.

D. Implementation

The implementation of the GITTW-based hybrid learning model using moodle e-learning was carried out at SMA Muhammadiyah 3 Gadung Surabaya, Indonesia, involving 80 students from the Grade 10 Science class during the first semester of the 2023-2024 academic year. The learning process commenced with an orientation on how to use the Moodle application, supported by a previously provided tutorial video. The instructional sessions on the topic of viruses were delivered in three meetings, each lasting 3 x 45 minutes.

The results of the rial implementation of the GITTW-based hybrid learning model through Moodle-based e-learning were valid and reliable, as presented in Table 8.

Table 8. *Test validity and reliability results*

Aspect	Average Score	Category
Validity	0.42 – 0.82	valid
Reliability	0.634	high
Difficulty Index	0.23 – 0.31	average - difficult
Discrimination Index	0.23 – 0.44	good

Table 8 shows that the developed test instrument demonstrates a good validity, ranging from 0.42 to 0.82, and high reliability (0.634), indicating a trustworthy measurement quality. However, a noteworthy finding lies in the difficulty index, which falls between 0.23 and 0.31, categorized as moderately difficult. This suggests that the test items were relatively challenging for most students.

At the Implementation stage, a practicality test of the GITTW-based hybrid learning model integrated with Moodle-based e-learning was conducted. The practicality test involved four teachers who completed a teacher response questionnaire. The results of this evaluation, which reflect the teachers' assessment of the practicality of the Moodle-based e-learning integrated with the GITTW strategy, are presented in Table 9.

Table 9. *Teacher response to moodle-based e-learning*

Aspect	Responses Percentage (%)	Practical Category
Learning Display	88.22	Very practical
Content	77.18	practical
Display	87.98	Very practical
Operation	89.77	Very practical
Language	85.67	Very practical

Table 9 indicates that teachers rated almost all aspects of the Moodle-based e-learning as highly practical, particularly in terms of operational ease (89.77%) and instructional design appearance (88.22%). However, a notable finding appeared in the content aspect, which received a score of only 77.18% and was categorized as practical rather than very practical. This suggests that although the platform was technically well-received, there remains room for improvement in the quality or depth of the instructional content to better align with pedagogical needs and teachers' expectations. The results of the practicality test of the GITTW-integrated Moodle-based e-learning as assessed by students are presented in Table 10.

The results of practicality test of the GITTW-integrated Moodle-based e-learning as assessed by students are presented in Table 10.

Tabel 10. *Student responses to moodle-based e-learning*

Aspect	Responses Percentage (%)	Practical Category
Material suitability	82.11	practical
Display	85.89	Very practical
Operation	80.67	practical
Language	85.77	Very practical

Table 10 shows that the operational aspect received the lowest score (80.67%) compared to other aspects, although it still falls within the practical category. Despite the platform's strong technical features, this result may indicate that some students experienced minor technical challenges or had limited digital skills in operating Moodle effectively. This is particularly relevant in the context of hybrid learning, which demands a higher degree of technological autonomy from students.

Based on the analysis of both teacher and student responses to the GITTW-integrated Moodle-based e-learning, the findings indicate that the developed product is highly practical and ready for implementation.

During the limited trial phase, the effectiveness of the GITTW-integrated Moodle-based e-learning, was evaluated. This was carried out using an essay-type assessment instrument designed to measure metacognitive skills. The results of the effectiveness test are presented in Table 11.

Table 11. *Product effectiveness results*

N-Gain Category	Percentage
Height increase	57.50 %
Medium increase	31.25 %
Low increase	11.25 %

Based on Table 11, an interesting finding emerges in the dominance of the high-gain category, indicating that the product has a significantly positive impact on learning outcomes. This suggests that the intervention provided through the product is highly aligned with the learners' needs and characteristics, enabling the majority of students to gain maximum benefit.

The results of the learning motivation questionnaire, which measures the aspects of attention, relevance, confidence and satisfaction, are presented in Table 12.

Table 12. *Student learning motivation results*

Category	Percentage
Very agree	37.50
Agree	51.25
Disagree	11.25
Very disagree	0.00

Table 12 shows that no respondents chose the "very disagree" category (0.00%), indicating that all participants responded positively to their learning experience. This reflects that the learning approach or media used was not only effective but also emotionally and cognitively accepted by students, creating a learning environment that supports internal motivation.

Discussions

This study developed a hybrid learning model integrated with the GITTW strategy and supported by educational materials, including lesson plans, student worksheets, evaluation instruments, learning motivation observation sheets, questionnaires, and a Moodle-based e-learning platform. All instructional materials were valid, effective, and practical. The classroom implementation of the Moodle-based e-learning system demonstrated improved student engagement and enthusiasm, facilitated by smartphone usage to access the Moodle application, where students independently searched for information to solve learning problems.

The Moodle-based e-learning platform can be accessed through http://tacticedu.com. This platform provides various learning resources, including biology materials, images, videos, animations, and learning activities for each session, such as attendance, discussion forums, chats, assignments, and quizzes. These features are designed to simulate active student engagement. The assignment feature, in particular, fosters students' ability to search the internet for problem-solving information, thus supporting innovative learning. As noted by Rasheed et al., (2020), innovative learning can be effectively achieved by combining content and resources from both face-to-face and online learning modalities.

Survey results indicate highly positive responses from both teachers and students toward the Hybrid Learning model integrated with GITTW strategies and the developed Moodle-based e-learning.

Teachers noted that the Moodle platform is visually engaging and provides content that effectively supports classroom instruction. It enables teachers to align their teaching with the planned model syntax and serves not only as a medium for content delivery but also as a platform for assigning and managing student tasks. Teachers also reported that Moodle facilitates content delivery both in-class and beyond, supporting the hybrid learning approach.

Student survey results also reveal increased interest and engagement in learning activities. The multimedia factures such as images and videos make the content more comprehensible and appealing. Students collaborate in groups with clearly defined roles, each utilizing Moodle via smartphones to complete tasks. The flexibility of the hybrid learning model allows students to self-direct and regulate their learning activities. This aligns with findings from de Oliveira et al., (2022), who argue that Moodle enhances active student engagement, fosters self-regulation, and promotes learner autonomy. Similarly, Chiu (2021), asserts that digital tools play a critical role in supporting student participation in hybrid learning environments.

The hybrid learning encourages students to stay motivated and engaged, especially when they can access video presentations via Moodle to reinforce understanding. This method helps students develop confidence and persistence in addressing complex problems. The e-learning platform also enables direct submission of assignments, eliminating the need for physical printing. The integration of interactive multimedia via Moodle has proven to increase students' learning motivation. Research by Helena and Deborah (2024) emphasizes that platforms such as Moodle significantly influence motivation due to their accessibility, interactivity, and flexibility, which align with students' talents and interests. This is supported by Frisnoiry and Darari (2020), who found that the use of Moodle substantially affects student motivation.

While Moodle supports both online and offline learning environments, it requires structured learning strategies to help students focus on understanding and solving problems scientifically. The GITTW strategy enhances this process by guiding students through investigation, solution planning, and the identification of optimal outcomes, all of which are facilitated by internet access and Moodle features. Mustapha et al. (2023) highlight that the integration of Moodle with structured learning strategies improves motivation and fosters positive learner perceptions. Similarly, Gamage et al. (2022) state that Moodle enhances the speed and efficiency of information retrieval, contributing to effective problem-solving. Thus, incorporating learning strategies within Moodle provides clear direction in achieving educational objectives.

The GITTW strategy adopted in this study is a cooperative learning model that emphasizes student autonomy, encouraging learners to take responsibility for planning and managing their own learning processes. It supports the development of independent learning skills. The structured syntax of GITTW in Moodle-based instruction guides students through stages of identifying problems, task delegation within groups, conducting investigations, analyzing solutions, and concluding with self-assessment to reflect on learning processes and outcomes (Listiana et al., 2020). Through this process, students are trained to work independently, collaborate in teams, solve problems, and take ownership of their learning, skills linked to the enhancement of metacognitive skills.

Above all, the integration of educational technology is vital for fostering self-regulated and independent learning. The interactive Moodle platform enables teachers to facilitate deeper student engagement. When paired with metacognitive guidance, students learn to plan, monitor, and evaluate their learning strategies to achieve goals in a hybrid learning context. The development of instructional materials integrating the GITTW strategy significantly support this model of learning. Listiana et al., (2023) emphasize that GITTW strategy promotes self-assessment and reflection and can be effectively applied in both online and face-to-face learning environments.

Conclusions

This study aims to develop a hybrid learning educational tool by integrating the GITTW strategy into instructional components, including lesson plans, evaluation sheets, and e-learning media like Moodle for the biology subject at the senior high school level. The results demonstrate that the developed products were valid, effective, and practical as they showed the potential to enhance students' metacognitive skills and learning motivation. These educational media are expected to support teachers in improving the quality of biology instruction and can be widely applied to other subjects, provided that the unique characteristics of both learners and subject matter are taken into account. Future studies could explore the development

of Moodle by integrating Augmented Reality (AR), enabling students to learn about and explore the human organ systems interactively. Through AR-enhanced learning, students would be able to access textual materials, watch instructional videos, and activate 3D models of human organs directly from their smartphones.

Limitations

This study has four limitations. First, the sample size was limited to 80 tenth-grade students from a single private school in Surabaya, Indonesia, which constraints the external validity and generalizability of the findings to a broader population. Moreover, the specific research context, characterized by uneven digital infrastructure, revealed that not all students had adequate access or sufficient skills to operate the Moodle platform, as indicated by the relatively lower operational response scores from students. Second, although Moodle was perceived as highly practical by both teachers and students, the effectiveness test was conducted on a small scale without a comparison group or a more robust experimental design. As such, it remains uncertain whether the observed improvements in learning outcomes were solely attributable to the intervention. Third, the data collected were predominantly quantitative, relaying on questionnaires, without the support of in-depth qualitative data such as interviews or observations that could provide a more holistic understanding of the learning experience. Fourth, the sustainability of Moodle use beyond the research phase was not evaluated. Therefore, further studies are necessary to investigate the broader and long-term implementation of Moodle in diverse educational settings.

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Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, L.L., F.R. and R.D.; methodology, R.D. and A.S.H.; formal analysis, F.R.; writing—original draft preparation, L.L.; writing—review and editing, L.L., and F.R.; Supervision, A.S.H. All authors have read and agreed to the published version of the manuscript.

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Validation of the Social Skills Rating System: The Serbian Preschool Teacher Version

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Abstract: Social competence is a key aspect of early development, with long-term implications for children's functioning in educational and social environments. Given its importance, it is essential to have reliable and valid instruments for assessing both social skills and challenging behaviors in early childhood. This study aimed to evaluate the psychometric properties, factorial structure, and measurement invariance across developmental status and age groups of the preschool teacher version of the Social Skills Rating System, which includes the Social Skills Scale and the Problem Behaviors Scale, within the Serbian preschool population. A total of 309 teachers provided evaluations for 450 children aged 3 to 7, including both typically developing children and those with developmental challenges. Confirmatory factor analysis supported the original structure of the Social Skills Rating Scale, with good overall model fit. While the Problem Behaviors Scale was retained in its original form, three items were removed from the Social Skills Scale due to low factor loadings or validity concerns, resulting in a refined 27-item version. Both scales demonstrated high internal consistency, convergent and discriminant validity. The present findings suggests that the instrument holds potential for assessing social skills and behavioral challenges in Serbian preschool children aged 3 to 7 years, including those with and without developmental disabilities, thereby extending its applicability beyond the originally intended age range of 3 to 5 years. Although preliminary psychometric results are promising, further research is needed to more robustly confirm its validity and reliability across broader populations and contexts.

Keywords: *social skills, problem behaviors, social skills rating system, validation, teacher rating, preschool.*

Introduction

Social skills are learned, socially acceptable behaviors that facilitate positive interactions with others. They involve both initiating and responding to social cues, reinforced by appropriate social feedback and shaped by context. Essentially, social skills enable individuals to engage effectively in various social settings (Little et al., 2017), and they are crucial for success in academic environments (e.g. Quílez-Robres et al., 2021). According to teachers, key social skills for thriving in school include active listening, following classroom rules and teacher instructions, seeking help when needed, collaborating with peers, and managing emotions in conflict situations (Gresham et al., 2011).

Social skills form the foundation of socially competent behavior and are essential for assessing social competence, which involves evaluating the quality of an individual's interactions (Dryburgh et al., 2020; Little et al., 2017). Deficits in social competence are a core feature of various disabilities. Children with emotional disabilities often struggle to establish and maintain meaningful relationships with peers and teachers, frequently exhibiting inappropriate behavior in everyday situations (Polloway et al., 2017). These interpersonal challenges are not limited to emotional disabilities but are also evident in other childhood disorders. For instance, diagnoses of attention-deficit/hyperactivity disorder, conduct disorder, and oppositional defiant disorder require clear evidence of clinically significant impairments in social function-

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ing (American Psychiatric Association [APA], 2013; World Health Organization [WHO], 2018). Similarly, autism spectrum disorder is characterized by severe and persistent deficits in reciprocal social interaction, often accompained by difficulties in forming, sustaining, and understanding relationships (APA, 2013; WHO, 2018). In defining intellectual disability, social skills are recognized as a key component within the broader concept of adaptive behavior (APA, 2013; WHO, 2018). As Brojčin et al. (2011) note, cognitive deficits in children with intellectual disability, reflected in lower IQ scores, delay the development of social skills. This delay often leads to social withdrawal and less favorable peer relationships.

A variety of methods are available for evaluating social skills, including observational assessments, projective techniques, self-report instruments, sociometric evaluations, and behavior rating scales. Among these, behavior rating scales—often used alongside direct behavioral observations—are widely regarded as the most reliable and practical approach for assessing children's social skills (Merrell, 2001).

The Social Skills Rating System (SSRS, Gresham and Elliott, 1990) is considered the gold standard for evaluating social skills in children aged 3–18 due to its comprehensive design. It is designed for screening and identifying children's social strengths and potential challenges, as well as supporting specialists in developing targeted interventions to enhance social behavior.

Recognizing that children's social behavior varies across different settings, the SSRS incorporates input from multiple evaluators (teachers, parents, and children) across diverse environments (preschool, school, home) and developmental stages. Since each group of respondents offers a unique perspective, Gresham and Elliot conducted separate analyses for the parent, teacher, and child versions of the instrument, revealing distinct factor structures. All versions of the SSRS Social Skills Scale assess three core factors: Cooperation, Assertion, and Self-Control. Additionally, the parent version includes an extra factor, Responsibility, while the child version incorporates Empathy. Beyond measuring social skills, the SSRS also evaluates problem behavior and academic performance, recognizing that problem behaviors often interfere with the development and application of social skills. The inclusion of an academic competence measure reflects the frequent co-occurence of poor social skills, competing problem behaviors, and below-average academic achievement (Gresham et al., 2011).

The SSRS has been widely used in research, both as a whole and through its individual scales, across diverse child populations, including low-income groups (Fantuzzo et al., 1998), post-institutionalized children (Julian and McCall, 2016), and various clinical groups. These clinical groups include individuals with intellectual disabilities (Brojčin and Glumbić, 2012; Jelić and Stojković, 2020; Memisevic and Biscevic, 2020), autism (Rankin et al., 2016), visual impairments (Bilić Prcić et al., 2015; Runjić et al., 2015), language impairments (Pentimonti et al., 2016), and attention-deficit/hyperactivity disorder (Van der Oord et al., 2005). Beyond research, the SSRS is frequently used in applied settings and in evaluating the effectiveness of social skills interventions (e.g., Goh et al., 2020). Additionally, it has served as a benchmark for the development and validation of new assessment tools (e.g. Arnesen et al., 2018; Fink et al., 2013; Gresham and Elliott, 2008; Gresham et al., 2010).

The SSRS demonstrates strong psychometric properties, with numerous studies confirming its validity and reliability. Research has examined various aspects of validity, with some studies focusing on reliability measures, such as internal consistency and test-retest reliability (e.g., Rich et al., 2008; Wang et al., 2011). Others have explored predictive, convergent, and discriminant validity, assessing its relationship with different constructs, criteria, or alternative social skills measures (e.g., Rich et al., 2008; Van der Oord et al., 2005; Wang et al., 2011).

Recognizing the influence of situational and cultural factors on social skills is essential for the development, validation, and meaningful interpretation of psychological measures in this domain. The assessment of social skills and related constructs is deeply shaped by the socio-cultural context in which social behaviors occur. Since assessment instruments reflects the values, beliefs, and communication norms of the culture in which they were developed, their applicability must be carefully considered when used in different cultural settings. Cultural norms—particularly in emotional expression, behavior regulation, and parental beliefs about child socialization—vary across societies (e.g. Cordaro et al., 2018; Deng et al., 2019; Minkov et al., 2018). As a result, behaviors deemed adaptive and appropriate in one culture may not be perceived the same way in another. Thus, an instrument's effectiveness in its original cultural context does not necessarily guarantee its reliability and validity in a different setting (Jurado et al., 2006). The SSRS was developed for English-speaking informants and standardized on children and adolescents in the United States. However, its psychometric properties have not yet been examined within the Serbian

socio-cultural context. To our knowledge, the only validation study conducted in Serbia involved an older population of children (12–18 years) and yielded a different factor structure from the original version, as determined through exploratory factor analysis (Jelić, 2015).

Considering the potential influence of the educational context on the implementation of assessment tools is also essential. In the United States, preschool includes children aged 3 to 5, whereas in Serbia, this stage extends from ages 3 to 6, covering both preschool and kindergarten years. Additionally, some preschool settings in Serbia accommodate 7-year-olds who begin first-grade within that calendar year. While having a single tool applicable to all children within a given educational framework would be practical, the SSRS preschool version, designed for 3 to 5-year-olds, may not fully capture the diverse age range of children attending Serbian kindergartens.

Given these considerations, the present study aims to evaluate the reliability and factorial structure of the preschool teacher version of the SSRS, which includes the Social Skills Scale and the Problem Behaviors Scale (Gresham and Elliott, 1990), within the Serbian preschool population. To address this aim, the main research questions are as follows:

1. Does the factor structure of the original SSRS Social Skills Scale, confirmed in a U.S. teacher sample, demonstrate good model fit when applied to a Serbian sample of preschool teachers? If so, does it show adequate internal consistency, convergent validity, and discriminant validity?
2. Does the factor structure of the original SSRS Problem Behaviors Scale, confirmed in the U.S. teacher sample, demonstrate good model fit in a Serbian sample of preschool teachers? If so, does it show adequate internal consistency, convergent validity, and discriminant validity?
3. Does the factor structure of both scales demonstrate measurement invariance across developmental status and age groups?

We hypothesize that the factors derived from the original Social Skills Scale—Cooperation, Assertion, and Self-Control—will be replicated in our sample of preschool teachers, along with the Internalizing and Externalizing problem behaviors factors from the Problem Behaviors Scale. If this structure is not confirmed, exploratory factor analysis will be conducted to identify the latent factor structure and reliability within the Serbian sample. Additionally, we hypothesize that the factor structure of the instrument will demonstrate measurement invariance across age groups (3–5 years vs. 6–7 years) and developmental status groups (children with developmental disabilities vs. typically developing children), thereby supporting its validity for diverse preschool populations. Our goal is to propose a version suitable for children aged 3 to 7 in Serbia, ensuring that a single instrument can effectively cover the entire preschool period.

Materials and Method

Participants and procedure

Participants were selected based on predefined criteria to ensure that the sample included a sufficient number of teachers working with children with developmental difficulties and those at risks, as well as a balanced representation of children across age and gender. Based on these criteria, the sample consisted of 309 preschool teachers reporting on 450 children, including 235 boys (52.2%) and 215 girls (47.8%), aged between 3 and 7 years (M = 5.73, SD = 1.05). Of these, 140 children (31.1%) were in the younger age group (3–5 years), and 310 children (68.9%) were in the older age group (6–7 years). Of the total sample, 61.3% were children with typical development, while 38.7% faced various developmental difficulties or risks, as outlined in Table 1. Identification of children with developmental difficulties and those at risk was based on the presence of an Individualized Education Plan and supporting documentation available for each child within the preschool institution.The two groups were similar in age, $t(448) = -1.37$, $p = .172$, and gender distribution, $\chi^2 = 2.484$, $p = .115$. All children attended inclusive preschool institutions spread across 14 different sites, encompassing both rural (fewer than 5000 inhabitants) and urban areas in Serbia.

The vast majority of participating preschool teachers were female (96.8%), with a mean age of 41.04 years (SD = 9.83). Most teachers had between 5 and 20 years of professional experience (41.1%), followed by those with over 20 years (32.4%), while 26.5% had less than 5 years of experience. Additionally, 10.03% of the teachers were employed in rural settings.

Table 1. *Sample characteristics*

	N	%	Gender		Age
			Boys N (%)	Girls N (%)	Years M (SD)
Typical development	276	61.3	136 (49.3)	140 (50.7)	5.68 (1.06)
Children with developmental difficulties/risks	174	38.7	99 (56.9)	75 (43.1)	5.82 (1.01)
Health problems	5	1.1			
Multiple disabilities	52	11.6			
Speech and language disorders	36	8.0			
Learning difficulties	17	3.8			
Motor difficulties	25	5.6			
Visual/ Hearing difficulties	23	5.1			
Emotional/behavioral problems	16	3.6			

Prior to data collection, the study was approved by the Ethics Committee for Research of the Faculty of Special Education and Rehabilitation, University of Belgrade. In addition, consent was obtained from the participating preschool and from the parents of the children whose social competencies were assessed by the teachers. Both parents and teachers received detailed information about the purpose of the research and were informed of their right to withdraw at any time without consequences.

Teachers completed the instrument within their preschool settings, under standardized conditions. Special attention was given to establishing good communication with the participants and addressing any initial questions or uncertainties about the process. In cases where participants encountered difficulties, researchers provided individual assistance, ensuring the accuracy and comprehension of the responses throughout the data collection process.

Instrument

The teacher version of the SSRS is a 40-item measure for assessing preschool children's social competence (Gresham and Elliott, 1990). According to the manual, the standardization was conducted on a heterogeneous sample, encompassing a wide range of educational classifications, such as children with learning disabilities, behavioral disorders, and intellectual disabilities. The SSRS consists of two core components: the Social Skills Scale (30 items) and the Problem Behaviors Scale (10 items), which assess the frequency of children's social skills and challenging behaviors. Each item is rated on a 3-point Likert scale (0 = never, 1 = sometimes, and 2 = very often).

The Social Skills Scale consists of three statistically derived domains: Self-Control, Assertion, and Cooperation. As outlined by Gresham and Elliott (1990), the Cooperation domain primarily evaluates skills related to a child's ability to collaborate with the teacher and follow classroom rules. This includes behaviors such as paying attention to the teacher's instructions, complying with directives, and maintaining focus despite peer distractions. In contrast, the Assertion domain focuses on the child's assertive behavior during interactions with both peers and adults. It includes behaviors such as initiating conversations, inviting peers to join group activities, offering compliments, and helping others. Furthermore, this domain also assesses the child's ability to assert themselves appropriately when facing unfair treatment or demands from the teacher. Finally, the Self-Control domain evaluates the child's ability to manage their emotions and respond effectively to conflicts with peers and teachers. It also examines the child's capacity to balance their own needs with those of others in social interactions, including behaviors like controlling emotions, responding appropriately to teasing, and taking turns during play.

The Problem Behaviors Scale includes two domains: Externalizing and Internalizing subscales. The Externalising subscale includes behaviors like temper tantrums, fidgeting, arguing, and fighting, while the Internalising domain focuses on behaviors and emotions such as anxiety, sadness, and social withdrawal.

Procedures for adapting the SSRS

Adaptations to the original SSRS (Gresham and Elliott, 1990) were made to account for sociocultural differences between the U.S. and Serbian contexts during the development of the Serbian version of the scale. The scale was initially translated from English into Serbian by two independent bilingual experts proficient in both languages, and then back-translated by a translator who was unaware of the original instrument. Discrepancies between the original and back-translated versions were resolved by the team of translators to ensure the translation was accurate and clear. Additionally, a panel of experts reviewed the translation to ensure linguistic and contextual appropriateness, aiming to achieve clarity and conceptual equivalence with the original version.

A university-based panel of experts in the fields of early childhood education, children's social competence, and special education, reviewed the translated instrument and discussed the content of each item to evaluate its validity, as well as its linguistic and cultural appropriateness. The panel reached a consensus, without major disagreements, that all items were clear, relevant, and appropriate within the context of preschool education in Serbia. They also concluded that the constructs and behaviors assessed by the scale (e.g., giving compliments to peers, appropriately expressing disagreement, responding to teasing) were easily understandable and culturally appropriate. Given the consistency of expert evaluations, a formal Content Validity Index (CVI) was not applied.

Additionally, cognitive interviews with end users were not conducted at this stage, as the consensus of experts provided a relevant and qualitatively grounded assessment of the cultural adequacy of the instrument's content. Instead, a focus group with 15 preschool teachers was organized to further examine the face validity of the instrument in terms of relevance, clarity, and appropriateness of item content (Oluwatayo, 2012), from the perspective of practitioners in preschool settings. Feedback from the focus group led to minor linguistic adjustments—such as expanding the phrase "Invites others to join in activities" into a more explicit expression ("Demonstrates initiative to socialize and invites peers to participate in shared activities") and clarifying items like "Puts work materials or school property away" by adding context emphasizing independence ("Regularly puts personal belongings and work materials in their designated place without needing reminders"). These minor modifications, along with expert evaluations, contributed to the assessment of the instrument's initial validity. Conceptual equivalence and construct validity were further evaluated through confirmatory factor analysis.

Statistical analysis

To assess the factor structure of the original SSRS, Confirmatory Factor Analysis (CFA) was conducted to evaluate the model fit for the current dataset. Given the ordinal nature of the items and significant deviations from normality, the analysis used the Diagonally Weighted Least Squares (DWLS) estimator (Li, 2016), implemented in JASP 19.3 via the lavaan package.

Model fit was assessed using several common fit indices: Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI), where values above 0.95 indicate a good fit, and values above .90 represent adequate fit (Bentler, 1990; Hu and Bentler, 1999); Root Mean Square Error of Approximation (RMSEA), with values below 0.06 indicating good fit and below .08 representing a reasonable fit (Browne and Cudeck, 1993; Steiger, 1990); and Standardized Root Mean Square Residual (SRMR), with values under .05 denoting a good fit and under .08 signifying an adequate fit (Hu and Bentler, 1999). According to the non-invariance criteria for unequal group sizes (Chen, 2007), invariance was supported when $\Delta CFI \leq .005$, combined with $\Delta RMSEA \leq .010$ or $\Delta SRMR \leq .025$ for testing metric invariance, and $\Delta SRMR \leq .005$ for testing scalar or residual invariance.

The reliability of the scales was assessed by examining the internal consistency of the factors, as indicated by both Cronbach's alpha and McDonald's omega coefficients. Convergent validity was considered satisfactory when the Average Variance Extracted (AVE) for each construct reached or exceeded .50 (Hair et al., 2019). To evaluate discriminant validity, the heterotrait-monotrait ratio (HTMT) was applied; values below .90 were interpreted as evidence that the constructs represent distinct dimensions (Henseler et al., 2015).

Results

To evaluate the suitability of the data for factor analysis, preliminary tests of sampling adequacy were conducted. The Kaiser–Meyer–Olkin measure yielded an excellent value of .94, suggesting sufficient intercorrelations among items. Additionally, Bartlett's test of sphericity was statistically significant, $\chi^2(435) = 10624.328$, $p < .001$, supporting the factorability of the correlation matrix. Descriptive statistics revealed that most items deviated from normality (Table 2). Z-scores for skewness and kurtosis exceeded the ±1.96 threshold for most items, indicating significant departures from normality. Most Social Skills Scale items showed negative skewness, suggesting responses were skewed toward higher ratings, while negative kurtosis values indicated a flatter distribution. For Problem Behaviors Scale items, skewness Z-scores ranged from 3.46 to 6.26, and kurtosis Z-scores ranged from 0.63 to 16.09, indicating significant positive skewness and heavy-tailed distributions.

Table 2. *Descriptive parameters of the SSRS*

Item	Min	Max	M	SD	Z Skew	Z Kurt
Social Skills Scale						
1	0	2	1.49	0.59	-5.79	-2.24
2	0	2	1.34	0.70	-5.09	-3.47
3	0	2	1.49	0.67	-8.18	-1.25
4	0	2	1.26	0.63	-2.32	-2.85
5	0	2	1.22	0.70	-2.79	-4.02
6	0	2	1.27	0.72	-4.01	-4.29
7	0	2	1.23	0.68	-2.77	-3.63
8	0	2	0.92	0.72	1.09	-4.66
9	0	2	1.54	0.64	-9.17	-0.01
10	0	2	1.57	0.58	-8.30	-0.37
11	0	2	1.12	0.72	-1.58	-4.56
12	0	2	0.66	0.68	4.66	-3.33
13	0	2	1.18	0.63	-1.45	-2.60
14	0	2	1.37	0.68	-5.37	-3.08
15	0	2	1.30	0.66	-3.62	-3.25
16	0	2	1.30	0.65	-3.35	-3.13
17	0	2	1.27	0.73	-4.03	-4.39
18	0	2	1.51	0.60	-6.78	-1.60
19	0	2	1.63	0.56	-10.40	1.96
20	0	2	1.19	0.65	-1.88	-3.05
21	0	2	1.36	0.64	-4.23	-2.90
22	0	2	1.44	0.61	-5.14	-2.50
23	0	2	1.14	0.63	-1.04	-2.33
24	0	2	1.33	0.66	-4.18	-3.21
25	0	2	1.33	0.70	-4.86	-3.60
26	0	2	1.02	0.64	-0.14	-2.49
27	0	2	1.36	0.66	-4.64	-3.05
28	0	2	1.05	0.61	-0.23	-1.54
29	0	2	1.39	0.70	-6.17	-2.97
30	0	2	1.21	0.74	-3.02	-4.77
Problem Behaviors Scale						
1	0	2	0.67	0.73	5.23	4.03
2	0	2	0.75	0.75	3.46	4.86
3	0	2	0.55	0.63	6.26	2.06
4	0	2	0.62	0.69	5.83	3.01
5	0	2	0.28	0.56	16.09	10.52
6	0	2	0.46	0.59	7.98	0.66
7	0	2	0.41	0.60	10.12	1.39
8	0	2	0.64	0.63	4.08	1.59
9	0	2	0.43	0.64	10.57	1.41
10	0	2	0.46	0.60	8.03	0.63

Social Skill Scale Analysis

Following the descriptive analysis, a CFA was performed to assess the factorial validity of the Social Skills Scale. The chi-square test was statistically significant ($\chi^2 = 1026.083$, $df = 402$, $p < .001$), indicating some discrepancy between the observed and model-implied covariance matrices. However, when using DWLS estimation, the chi-square statistic is not considered the most reliable indicator of model fit as its distribution is adjusted due to partial information in the weight matrix, which can affect its accuracy (Kyriazos and Poga-Kyriazou, 2023; Li, 2016). Instead, the chi-square to degrees of freedom ratio (χ^2/df) is commonly used, with values below 3.00 indicating good fit and values under 5.00 considered acceptable. To provide a more comprehensive assessment of model adequacy, we also reported main fit indices, including CFI, TLI, RMSEA, and SRMR.

The model demonstrated good overall fit, with $\chi^2/df = 2.55$, CFI = 0.983 and TLI = 0.982 both exceeding the recommended 0.95 threshold, indicating excellent comparative fit. RMSEA (0.059; 90% CI [0.054, 0.063]) was below the 0.06 cutoff, suggesting acceptable approximation error. Additionally, SRMR (0.073) fell within the acceptable range (< 0.08), further supporting the adequacy of the model fit. While internal consistency, as indicated by Cronbach's Alpha and McDonald's Omega coefficients, demonstrated excellent reliability, the convergent and discriminant validity values did not fully meet the threshold criteria.

The AVE for Factor 1 (Cooperation) and Factor 2 (Assertion) was above the recommended .50 threshold (.52 and .51, respectively), indicating good convergent validity. However, Factor 3 (Self-Control) had an AVE of .48, slightly below the threshold, suggesting weaker convergent validity. Given that HTMT values above .90 may indicate poor discriminant validity due to conceptual overlap between factors, the results suggest that Factor 1 and Factor 2 (HTMT = .98) may not be sufficiently distinct constructs, potentially requiring further refinement of the model. To address these concerns, we conducted a more detailed analysis of all obtained parameters, with a particular focus on examining the indicator loadings and modification indices.

All standardized factor loadings were statistically significant ($p < .001$), indicating that each observed variable significantly contributed to its respective latent construct. However, for Factor 1 (Cooperation), standardized loadings ranged from .348 (CO12) to .840 (CO6), with CO12 exhibiting the weakest loading, indicating that the variance it shared with the latent factor was relatively low compared to other items. For Factor 2 (Assertion), all items showed substantial contributions to the factor, with standardized loadings ranging from .591 (AS3) to .778 (AS19). For Factor 3 (Self-Control), standardized loadings ranged from .384 (SC26) to .785 (SC21), with SC26 exhibiting the weakest loading. Similar to item CO12, item SC26 had a loading below the recommended threshold of .40 for acceptable item reliability, suggesting that both items should be removed from the model (Hamid et al., 2017). Accordingly, items CO12 and SC26 were excluded, and the CFA was rerun.

Comparative fit indices improved relative to the initial model, with $\chi^2/df = 2.11$, CFI increasing to 0.989 and TLI to 0.988. RMSEA decreased to 0.050 (90% CI [0.045, 0.055]), and SRMR dropped to 0.067, indicating a more refined and better-fitting model. All AVE values exceeded .50, indicating adequate convergent validity, while HTMT values (.89, .90, and .82) supported discriminant validity. However, the borderline HTMT value of .90 between Factors 1 and 3 warranted further consideration of construct overlap. Examination of modification indices revealed substantial cross-loadings for item SC14, with a modification index of 15.56 on Factor 1 and 22.12 on Factor 2. Consequently, this item was removed, and the CFA was rerun again.

The exclusion of SC14 reduced the HTMT value between Factors 1 and 3 to .88, and between Factor 2 and 3 to .79 indicating reduced factor overlap and improved discriminant validity. AVE values for all three factors were as follows: Factor 1 (.58), Factor 2 (.51), and Factor 3 (.52), satisfying the threshold for convergent validity.The 27-item model demonstrated good fit, with $\chi^2/df = 2.04$, CFI = 0.990, TLI = 0.989, RMSEA = 0.048 (90% CI [0.043, 0.053]), and SRMR = 0.066, not statistically significant, but showing a better fit than the initial model. Factor loadings and additional parameters of the final model are presented in Table 3. Standardized factor loadings ranged from .554 to .853 confirming that all retained items load meaningfully on their respective factors. These findings support both the construct validity and conceptual equivalence of the adapted instrument.

Table 3. *Factor loadings – Social Skills Scale*

						95% Confidence Interval		
Factor	Item	Estimate	Std. Error	z-value	p	Lower	Upper	Std. Est. (all)
Factor 1	CO1	0.417	0.020	20.348	< .001	0.377	0.457	0.706
	CO6	0.617	0.022	28.523	< .001	0.575	0.660	0.853
	CO9	0.508	0.025	20.045	< .001	0.459	0.558	0.794
	CO10	0.464	0.019	24.376	< .001	0.427	0.502	0.802
	CO16	0.485	0.025	19.292	< .001	0.436	0.535	0.749
	CO18	0.441	0.026	16.865	< .001	0.390	0.492	0.738
	CO22	0.467	0.022	21.422	< .001	0.424	0.510	0.767
	CO27	0.443	0.029	15.160	< .001	0.386	0.500	0.672
	CO29	0.523	0.027	19.574	< .001	0.471	0.575	0.752
Factor 2	AS2	0.484	0.030	16.353	< .001	0.426	0.542	0.696
	AS3	0.392	0.035	11.311	< .001	0.324	0.460	0.587
	AS5	0.522	0.026	19.991	< .001	0.471	0.573	0.749
	AS8	0.527	0.023	22.964	< .001	0.482	0.572	0.730
	AS11	0.536	0.025	21.860	< .001	0.488	0.584	0.747
	AS17	0.546	0.026	20.920	< .001	0.495	0.597	0.749
	AS19	0.439	0.025	17.384	< .001	0.389	0.488	0.782
	AS24	0.436	0.026	16.790	< .001	0.385	0.487	0.658
	AS25	0.464	0.027	17.170	< .001	0.411	0.516	0.663
	AS30	0.560	0.026	21.641	< .001	0.509	0.611	0.760
Factor 3	SC4	0.351	0.033	10.615	< .001	0.286	0.415	0.554
	SC7	0.429	0.033	13.190	< .001	0.365	0.492	0.633
	SC13	0.496	0.025	19.483	< .001	0.443	0.542	0.777
	SC15	0.488	0.024	20.558	< .001	0.441	0.534	0.740
	SC20	0.467	0.026	18.293	< .001	0.417	0.517	0.718
	SC21	0.510	0.026	19.870	< .001	0.460	0.561	0.802
	SC23	0.496	0.025	19.632	< .001	0.446	0.545	0.788
	SC28	0.440	0.024	17.993	< .001	0.392	0.488	0.715

Legend: F1 = Cooperation; CO = Cooperation items; F2 = Assertion; AS = Assertion items; F3 = Self-Control; SC = Self-Control items; Std.all = Standardized Estimate on all variables

All three factors of the Social Skills Scale showed excellent internal consistency (Factor 1: ω = .92, α = .92; Factor 2: ω = .90, α = .91; Factor 3: ω = .89, α = .89). The overall scale also demonstrated high reliability (ω = .96, α = .96), indicating strong internal consistency across all items.

Problem Behaviors Scale Analysis

In the analysis of the second part of the SSRS scale related to problem behaviors, which originally consists of two factors, CFA was conducted to assess the distribution of items into factors. The results indicated good fit indices, with all relevant values meeting the recommended thresholds. The chi-square test for the factor model was significant (χ^2 = 53.479, *df* = 34, *p* = .018), but other fit indices were excellent: χ^2/df = 1.57, CFI = 0.995, TLI = 0.993, RMSEA = 0.036 (90% CI [0.015, 0.054]), and SRMR = 0.054. AVE values for Factors 1 (.54) and 2 (.59) exceeded .50, indicating adequate convergent validity, and the HTMT ratio (.82) supported discriminant validity (sufficient distinction between factors). Factor loadings and additional parameters of the model are presented in Table 4.

Table 4. *Factor loadings – Problem Behaviors Scale*

						95% Confidence Interval		
Factor	Item	Estimate	Std. Error	z-value	p	Lower	Upper	Std. Est. (all)
Factor 1	EPB31	0.439	0.017	25.838	< .001	0.406	0.473	0.599
	EPB32	0.552	0.019	29.314	< .001	0.515	0.589	0.731
	EPB33	0.462	0.017	26.829	< .001	0.428	0.496	0.734
	EPB34	0.601	0.019	32.127	< .001	0.565	0.638	0.874
	EPB37	0.430	0.017	25.217	< .001	0.397	0.464	0.713
	EPB38	0.459	0.017	26.406	< .001	0.425	0.493	0.729
Factor 2	IPB35	0.405	0.020	20.139	< .001	0.365	0.444	0.725
	IPB36	0.481	0.020	24.112	< .001	0.442	0.520	0.811
	IPB39	0.506	0.021	23.688	< .001	0.464	0.548	0.793
	IPB40	0.437	0.019	22.610	< .001	0.399	0.475	0.732

Legend: F1 = Externalized Problem Behaviors; EPB = Externalized Problem Behaviors items; F2 = Internalized Problem Behaviors; IPB = Internalized Problem Behaviors items; Std.all = Standardized Estimate on all variables.

All standardized factor loadings were statistically significant ($p < .001$), supporting the hypothesized two-factor structure of the Problem Behaviors Scale (Table 4). For Factor 1 (Externalizing Problem Behaviors), standardized loadings ranged from .599 (EPB31) to .874 (EPB34), indicating moderate to strong relationships between the items and the latent construct. Similarly, Factor 2 (Internalizing Problem Behaviors) showed standardized loadings ranging from .725 (IPB35) to .811 (IPB36), also reflecting strong item-factor associations. These results suggest that all items are good indicators of their respective latent factors and support both the construct validity and conceptual equivalence of the adapted instrument.

The analysis of convergent and discriminant validity revealed that the AVE values for each factor exceed .50, indicating adequate convergent validity. Moreover, the HTMT ratios for all factor pairs were below the .90 threshold, confirming adequate discriminant validity and clear differentiation between the constructs. These findings suggest that the factors are well represented by their indicators and sufficiently distinct from each another.

The Problem Behaviors Scale demonstrated good internal consistency for both factors (Factor 1: ω = .87, α = .87; Factor 2: ω = .85, α = .85), while the overall scale showed excellent reliability (ω = .91, α = .91).

The results confirmed our hypothesis that the factors derived from the original Social Skills Scale—Cooperation, Assertion, and Self-Control—were replicated in our sample of preschool teachers, along with the Internalized and Externalized problem behavior factors from the Problem Behaviors Scale.

Measurement invariance across development status and age groups

Addressing the third research question, the invariance of the SSRS scales (Social Skills and Problem Behaviors) across developmental status (Table 5) and age groups (Table 6) was tested following the criteria defined by Chen (2007) for unequal group sizes.

Table 5. *Measurement invariance across developmental status on SSRS scales*

SSRS scales	Invariance level	CFI	ΔCFI	RMSEA	ΔRMSEA	SRMR	ΔSRMR
Social skills	Configural	.989		.050		.079	
	Metric	.990	.001	.047	-.003	.078	-.001
	Scalar	.991	.001	.045	-.002	.078	.000
Problem behaviors	Configural	.992		.042		.074	
	Metric	.994	.002	.039	-.003	.071	-.003
	Scalar	.996	.002	.030	-.009	.071	.000

The observed changes in CFI, RMSEA, and SRMR values across different levels of invariance testing (metric vs. configural, scalar vs. metric) for developmental status ranged from 0 to .003, with the exception of a scalar invariance difference of .009 in RMSEA on the Problem Behaviors Scale, which remains within acceptable limits. Similarly, invariance testing across age groups showed changes in fit indices ranging from 0 to .004, with RMSEA differences of .008 for scalar invariance on the Problem Behaviors Scale and .009 for metric invariance on the Social Skills Scale, both within acceptable thresholds.

Table 6. *Measurement invariance across age on SSRS scales*

SRSS scales	Invariance level	CFI	ΔCFI	RMSEA	ΔRMSEA	SRMR	ΔSRMR
	Configural	.984		.061		.086	
Social skills	Metric	.988	.004	.052	-.009	.082	-.004
	Scalar	.989	.001	.050	-.002	.082	.000
	Configural	.994		.036		.071	
Problem behaviors	Metric	.994	.000	.037	.001	.070	-.001
	Scalar	.996	.002	.029	-.008	.070	.000

These results confirm that the structure of both the Social Skills and Problem Behaviors Scales remains invariant across developmental status and age groups (3–5 and 6–7 years). However, as presented in Table 6, the SRMR for the Social Skills Scale across age groups is slightly elevated at .086. This minor increase can be attributed to the unequal group sizes (310 vs. 140). As noted by Chen (2007), slight deviations above .08 in SRMR values are not uncommon under such conditions.

Considering the observed fit indices and invariance test results, we confirm that the SSRS instrument, validated within a sample of preschool teachers in our context, demonstrates measurement invariance across both developmental status and age groups within the preschool population.

Discussion

The aim of this study was to validate the factor structure of the original teacher version of the SSRS (Gresham and Elliott, 1990) in a sample of preschool teachers in Serbia. The SSRS was originally designed to assess the social competence of children aged 3 to 5 years based on evaluations by U.S. teachers. The instrument consists of two main scales: the Social Skills Scale and the Problem Behaviors Scale.

The original Social Skills Scale comprises three subscales-Cooperation, Assertion, and Self-Control—each containing 10 items each. Our first research question addressed whether the factor structure of the original Social Skills Scale would demonstrate a good model fit in a sample of preschool teachers in Serbia. The original three-factor model, consisting of 30 items corresponding to the Cooperation, Assertion, and Self-Control subscales, demonstrated good fit indices and high reliability, as indicated by Cronbach's Alpha and McDonald's Omega coefficients. However, convergent and discriminant validity fell below the recommended thresholds in our sample. Specifically, the AVE for the Self-Control factor was below .50 (Hair et al., 2019), and HTMT analysis revealed correlations between Cooperation and Assertion subscales that exceeded the .90 threshold (Henseler et al., 2015).

To address these issues, several modifications were made. Based on a detailed analysis of the data and guided by both theoretical and empirical criteria outlined by Hamid et al. (2017) and Hair et al. (2019), two items with low factor loadings (< .40) were removed: one from the Self-Control factor (*Receives criticism well*) and one from the Cooperation factor (*Introduces himself or herself to new people without being told*). In addition, the removed Cooperation item exhibited high cross-loadings with the Assertion factor. This overlap is theoretically justified, as assertion encompasses traits such as taking initiative, confident behavior, and self-presentation, which can also contribute to cooperative behavior (e.g., Vagos and Pereira, 2019). Furthermore, one additional item was removed due to a lack of discriminant validity between Cooperation and Self-Control, as indicated by an HTMT value above .90 (Henseler et al., 2015), suggesting considerable factor overlap. Although originally assigned to the Self-Control factor, this item (*Cooperates with peers without prompting*), is conceptually more aligned with the Cooperation factor.

These slight modifications, guided by both statistical criteria and theoretical considerations, improved the model's validity and fit indices while maintaining high internal consistency. Cronbach's Alpha

and McDonald's Omega coefficients ranged from .89 to .93 for each factor, and .96 for the overall scale. The revised model includes 27 out of the 30 original items: 9 items in the Cooperation subscale, 8 items in the Self-Control subscale, and all 10 items in the Assertion subscale. Consistent with psychometric literature on latent structure analysis (e.g., Brown, 2015; Kline, 2016), such modifications do not undermine the theoretical integrity of the model as long as the latent factor structure remains intact. In other words, aside from the three removed items, all other items were consistently aligned with the original version, indicating that preschool teachers in both Serbia and the United States similarly perceive and differentiate cooperation, assertion, and self-control in children.

Correlations among the factors confirmed that these social skills represent distinct yet interrelated dimensions, collectively forming a unified construct of social skills. Furthermore, the high internal consistency coefficients indicate that the factors consistently reflect the underlying social competence construct. However, reliability values exceeding .90 may not necessarily represent "excellent" internal consistency, as they can suggest item redundancy (Hamid et al., 2017). This raises the possibility that some items within each factor may overlap in content or fail to provide distinct information about the construct being measured. Similarly, the initial HTMT values exceeding the recommended threshold of .90 indicate substantial overlap between Cooperation and Assertion, as well as Cooperation and Self-Control. These findings are consistent with previous results reported by Gresham and Elliott (1990), as well as with studies conducted across different educational levels, age groups, and informant types (e.g., Jelić, 2015; Whiteside et al., 2007; Van der Oord et al., 2005), which also reported moderate to strong correlations between these factors. This pattern reflects the complex nature of social skills, in which various components are inherently interconnected. Although constructs such as cooperation, assertion, and self-control are theoretically distinct, they are often closely related in practice.

Our second research question investigated whether the factor structure of the original Problem Behaviors Scale, confirmed in the U.S. sample of teacher, would demonstrate good model fit in a Serbian sample of preschool teachers. The Problem Behaviors Scale includes two subscales: Externalizing Behaviors (6 items) and Internalizing Behaviors (4 items). The two-factor structure replicated well, with very good model fit indices. Reliability analysis, including Cronbach's Alpha and McDonald's Omega coefficients, revealed significant values above .80 for both subscales. HTMT correlations and AVE metrics further confirmed the psychometric quality of the Problem Behaviors Scale in the Serbian sample.

Our final research question examined measurement invariance across developmental status and age groups. Multigroup analyses confirmed that both the Social Skills Scale and the Problem Behaviors Scale demonstrate measurement invariance across these groups, indicating that the instrument reliably assesses social competence among Serbian preschool children regardless of developmental differences or age.

Although the original SSRS was designed for children aged 3 to 5 years, our results confirm its applicability and reliability for assessing social skills and problem behaviors in Serbian preschool children aged 3 to 7 years. For the Social Skills Scale, three items were removed, resulting in a revised version of the scale with 27 items, compared to the original 30. The Problem Behaviors Scale was fully replicated as it appeared in the original version. The modified version of the SSRS, reflecting these changes, is provided in the appendix.

Based on the present findings, the instrument shows promise for evaluating both typically developing children and those with developmental disabilities (e.g., autism, intellectual disability, and other challenges). While this suggests potential suitability for inclusive preschool settings, clinical contexts, and group-based research, further evidence, particulary external validity, is needed to fully confirm its appropriateness across diverse populations. Nonetheless, the instrument may support the development of individualized programs to enhance children's social competence and provide useful information for group-based assessments in research.

Limitations and Future Directions

Despite its contributions, this study has some limitations that warrant further investigation. The sample included only preschool teachers. Although measurement invariance was confirmed across groups defined by developmental status and age, future studies should examine whether these results generalize across different informant types (e.g., special education teachers) and across SSRS versions (e.g., the parent form). In addition, while the sample encompassed participants from both urban and rural

environments, the proportion of respondents from rural areas was limited to approximately 10%. Due to this imbalance, the sample cannot be considered fully representative of the rural preschool teacher population in Serbia. Future research should aim to recruit a more balanced sample to better reflect the diversity of educational contexts across urban and rural areas.

Although confirmatory factor analysis supported the conceptual equivalence and factorial validity of the adapted instrument, this study did not include formal quantitative assessments of content validity (e.g., Content Validity Index) or cognitive interviews due to reasons detailed in the methodology section. Future studies could further strengthen the adaptation process by incorporating additional qualitative methods and formal content validity indices.

Establishing inter-rater reliability between teacher and parent reports would provide a more comprehensive view of children's social behavior and further support the broader applicability of the scale.

Additionally, this study did not include a comparison with other similar instruments, which limits the ability to evaluate the SSRS's external discriminant validity. Future research could address this gap by comparing the SSRS with other well-established measures of social skills, thereby providing further support for its psychometric properties. Such comparisons would offer a more comprehensive understanding of how the SSRS differs from other tools in assessing social competence and its applicability across diverse settings.

Finally, the high inter- and intra-factor correlations—reflected in both Omega/Alpha coefficients and HTMT values—underscore the nuanced and interconnected nature of social skills. While this shared variance aligns with the theoretical expectations for closely related competencies, it also complicates the interpretation of the factors as entirely distinct. These results suggest a need for careful item selection to balance reliability and construct validity. Future research could refine the instrument by reducing item redundancy or applying alternative modeling approaches, such as bifactor or second-order models, to better distinguish shared from unique variance across dimensions.

Conclusion and implications

Social skills are critical for positive outcomes in various social settings. A validated tool for assessing these skills and challenging behaviors is a crucial step in supporting early childhood development and fostering children's social competencies. This study represents the first empirical construct validation of the SSRS teacher form (Gresham and Elliott, 1990) in Serbia. By confirming the original three-dimensional structure with slight modifications, this research provides a reliable instrument for evaluating and monitoring the development of social skills and problem behaviors in children aged 3 to 7 years. Validating the modified model with a new sample is essential to ensure its stability and robustness. Additionally, the study offers an opportunity for researchers from other countries to compare their findings with ours.

Although this study did not examine the relationship between social skill deficits and challenging behaviors, the validated SSRS provides a reliable foundation for future research on these connections. Identifying social skill deficits in both typically and atypically developing children supports early interventions to enhance social competencies and prevent problem behaviors.

Future research should focus on validating the SSRS parent form, as differences in how parents and teachers assess social skills and behaviors, especially for children with developmental disabilities, could offer valuable insights for tailored interventions. Additionally, exploring the SSRS constructs across different educational levels (from preschool to high school) and from various sources (e.g. parents, teachers, and special educators) would broaden its applicability and deepen our understanding of social skill development, contributing to a more holistic approach to promoting social competence in diverse educational settings.

Conflict of interests

The authors declare no conflict of interest.

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Appendix A: Serbian Version of the Modified SSRS - Item Content and Reliability by Factor

Skala socijalnih veština (Social Skills Scale)

F1: Kooperativnost (α = .92; ω = .92)
1. Pridržava se vaših uputstava.
6. Završava svoje obaveze i zadatke bez vašeg podsticanja na to.
9. Rado učestvuje u zajedničkim i grupnim aktivnostima.
10. Izvršava zadatke u skladu sa vašim instrukcijama.
16. Vreme koristi na prikladan način dok čeka pomoć vaspitača.
18. Vreme predviđeno za aktivnosti po izboru dete koristi na prihvatljiv način.
22. Završava zadatke u predviđenim rokovima.
27. Bez opominjanja na to, uredno odlaže svoje stvari i radni material na predviđeno mesto.
29. Pridružuje se aktivnosti ili grupi, bez da mu se to kaže.
F2: Asertivnost (α = .91; ω = .90)
2. Lako sklapa prijateljstva.
3. Na prikladan način saopštava kada smatra da ste bili nepravedni prema njemu/njoj.
5. Na odgovarajući način izražava sumnju u pravila koja smatra nepravednim.
8. U primerenim situacijama daje komplimente vršnjacima.
11. Pomaže Vam i kada to izričito ne zatražite od njega.
17. Govori lepe stvari o sebi u skladu sa situacijom.
19. Reaguje na pravi način kada mu se uputi kompliment i pohvala.
24. Inicira komunikaciju sa vršnjacima.
25. Inicira druženje i poziva vršnjake da mu se pridruže u nekoj aktivnosti.
30. Dobrovoljno pomaže vršnjacima u rešavanju zadataka.
F3: Samokontrola (α = .89; ω = .89)
4. Prikladno reaguje na zadirkivanja vršnjaka.
7. Kontroliše gnev u konfliktnim situacijama sa odraslima.
13. Prihvata ideje i predloge vršnjaka u vezi grupnih aktivnosti
15. Strpljivo čeka svoj red u igri ili drugim grupnim aktivnostima.
20. Dobro kontroliše emocije u konfliktima sa vršnjacima.
21. Pridržava se i sledi pravila u igrama i aktivnostima sa drugim vršnjacima.
23. Prihvata kompromis u konfliktnim situacijama izmenom sopstvenih ideja. u cilju postizanja dogovora.
28. Na adekvatan način reaguje na pritisak vršnjaka.

Skala problematičnog ponašanja (Problem Behaviors Scale)

F1: Eksternalizovani problemi (α = .87; ω = .87)
31. Ima napade besa.
32. Stalno se vrpolji, ne može da sedi na jednom mestu.
33. Bez realnog povoda, raspravlja se sa drugima.
34. Ometa rad.
37. Tuče se sa drugima.
38. Ne poštuje pravila.
F2: Internalizovani problemi (α = .85; ω = .85)
35. Kaže da njega (nju) niko ne voli.
36. Čini se da je usamljen (usamljena).
39. Ispoljava anksioznost u grupi druge dece.
40. Deluje kao da je tužan (tužna) ili depresivan (depresivna).

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Enhancing Early Childhood Students' Computational Thinking Competency Through Digital Game-Based Learning

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Abstract: This study investigated how the computational thinking competencies of students classified in the early childhood category can be developed through digital game-based learning. Computational thinking is a way of thinking that includes problem solving, algorithmic thinking and logical inference skills is considered an important competence that should be acquired at an early age. Digital game-based learning stands out as a powerful tool for developing computational thinking skills while providing a fun and motivating environment by ensuring the active participation of students. Within the scope of the research, the effects of digital game-based learning activities on students' computational thinking skills were examined by experimental method, one of the quantitative research methods. In this study, a 4-week training activity was conducted for the experimental and control groups determined during the research process to develop computational thinking skills in 5-year-old pre-school children. The study group consists of 50 students in the 5-year-old age group studying in the pre-school class of a state institution. In the study, student groups were divided into experimental and control groups. The experimental and control groups consisted of 25 students. The achievement test prepared for the cognitive domain was used as a pre-test and post-test as the data collection tool. In addition to this data collection tool, an evaluation rubric was also used in the study. The findings showed that digital game-based learning methods positively affect the development of computational thinking skills in early childhood. In light of these findings, recommendations were made in the study for the integration of digital games into relevant educational programs and the promotion of computational thinking at an early age.

Keywords: *digital game-based learning, computational thinking, early childhood, experimental method.*

Introduction

The early childhood period, which covers the age range of 0-6, is a critical period in which the cognitive, social and emotional development of individuals is based. Skills acquired during critical periods affect children's future learning processes and academic success. Therefore, it is of great importance to implement such effective learning methods at an early age. During this period, children show rapid change in multiple areas of cognitive development (Bakioglu and Karamustafaoglu, 2022). It is important to organize the educational materials prepared for children in this age group in accordance with their developmental areas in order to create an environment that includes stimuli for learning experiences (Can Yasar and Aral, 2010).

Early childhood is a period in which the brain develops rapidly. During the cognitive development process, children gain skills such as acquiring knowledge, using language appropriately, reasoning, and problem solving (Gardiner and Garner, 2010). According to related research, state that in order to support the cognitive development of children, presenting appropriate content or organizing educational materials in line with the thoughts, hypotheses, and solution suggestions they put forward is of great importance for their cognitive development (Yıldız and Zengin, 2021).

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In another study, it was stated that environmental richness can be created through play to support cognitive development in children (Fisher et al., 2018). Other research emphasizes that games play an important role in the emotional, linguistic, social, physical, and especially cognitive development of children (Yavuzer, 2010).

The 21st century is a period in which digitalization has accelerated and can be called the computer age. In this age, it is becoming increasingly important for individuals to develop the ability to think with computer logic and acquire programming skills. It has developed the computational thinking skill that the logical functioning of computers can also affect humans. Acquiring computational thinking skills and applying them in daily life stands out as a great necessity for individuals. According to related research, states that programming or computer skills are not needed specifically for computer scientists (Wing, 2008). In other research, also define computational thinking as a type of logical thinking that everyone has (Kim et al., 2013). In addition, it is stated that cognitive thinking skills, which are shown among the 21st century skills, include basic competencies such as algorithmic thinking and problem solving expected from individuals (Tezer et al., 2024).

In the century we are in, technological developments have also created radical changes in the game of playing. The proliferation of digital platforms has enabled children to move from traditional games to digital games that they interact with through electronic devices. This process has changed both children's understanding of entertainment and their social relationships. The increasing popularity of digital games in all age groups indicates that they have positive effects on children's development (Talan and Kalınkara, 2020). It is stated that digital games have the potential to provide a more interesting learning environment and support learning by structuring learning processes, as well as having positive effects on cognitive skills such as reasoning, critical thinking, problem solving, and ensuring the permanence of learning (Granic et al., 2014; Guntepe and Donmez, Usta, 2017; Li et al., 2020). According to other research, digital games improve children's skills such as planning, problem solving, observation, mathematical thinking, hypothesizing and testing, creativity, and collaborative learning (Gozum and Kandır, 2021). Another research stated that the correct use of technology by children in the pre-school period can have positive effects, improve their creativity and contribute to their self-confidence (Haugland, 2000).

The concept of computational thinking, first put forward by Wing (2006), includes ways of solving problems, designing systems, and understanding human behavior. Computational development in early childhood includes children's skills in problem solving, logical thinking, decision making, and participation in creative processes. Utilizing common points between digital games and computational thinking can contribute to this development process. That games help children develop problem-solving strategies, support algorithmic thinking skills, and establish logical connections (Bers, 2018).

Computational thinking includes the skills to analyze complex problems, develop solution strategies by breaking these problems into smaller pieces, create algorithms, and optimize solution processes. That the challenges encountered in games are similar to the basic principles of computational thinking, where players systematically take the problem-solving process and try various solutions by (Shute et al., 2017; Wing, 2006), states that overcoming an obstacle encountered in the game requires the player to solve this obstacle by dividing it into smaller sub-parts and establishing relationships between these parts, which is one of the basic principles of computational thinking. Additionally, the repetitive experience and opportunities to learn from failure that games offer are very similar to the trial-and-error processes encountered in computer programming. In this case, computer games can be considered as tools that provide players with the basics of computational thinking in a fun and interactive way.

A quasi-experimental research design with a pretest-posttest control group was used for this study. The study group consisted of sixth-grade middle school students. Lessons were conducted for the experimental group using a BID block-based coding tool. The results show that the experimental group had much higher mathematics achievement than the control group (Top and Arabacıoglu, 2024).

In this study, the Bee-Bot application was preferred for early childhood robotic coding education. Bee-Bot is an educational robot specifically designed to develop preschool children's algorithmic thinking, understanding of directional concepts, problem-solving, and sequencing skills. Its physical structure and ease of programmability support children's learning through concrete experiences. However, the literature also includes other robotic tools that can be used in early childhood education. For example, Doc Robot, developed by the company Clementoni, is another educational robot that similarly aims to enhance children's coding-based thinking skills. In addition to fostering logical thinking, directional awareness, and

problem-solving, Doc Robot is designed to teach basic concepts such as letters, numbers, colors, and animals (dikkatatolyesi.com, turascandinavia.com). Notably, its "smart mode" feature allows the robot to recognize its position on game cards and provide children with various tasks, making the learning process more interactive. In this context, Doc Robot, like Bee-Bot, is a programmable educational tool suitable for preschool use and offers an alternative depending on the goals and conditions of implementation. However, in this study, Bee-Bot was deemed a more appropriate choice considering the targeted learning outcomes and the practical conditions of the application.

Related Research

A game was designed by (Zhao, 2017), that includes the basic elements of computational thinking, such as problem solving, abstraction, algorithmic thinking, conditional logic, iterative thinking, and debugging. The results of the study revealed that students showed a significant increase in their computational thinking skills after playing the game for less than two hours. As a result of the study conducted by (Ciftci et al., 2018), it was revealed that digital games have positive effects on programming self-efficacy, computational thinking, reflective thinking about problem solving and the ability to follow developments in the field of computers. Investigated the effects of educational games on students' basic knowledge of object-oriented programming and computational thinking skills. According to the findings of the study, the developed educational digital game contributed to the students' learning the basic concepts of object-oriented programming and developing their computational thinking skills, were presented by Akkaya (2018).

In their research to determine at which education levels digital games can be used, Aksoy (2021) stated that digital games can be used at all levels of education, but they are more suitable, especially for younger age groups. In other research, the effects of science teaching with educational digital games and in-class educational games on the cognitive development levels of pre-school students were examined (Yıldız and Zengin, 2021). At the end of the research, it was revealed that the relevant methods were effective in increasing the cognitive development of pre-school students. In this study (Aksoy, 2021), the views of pre-school teachers on the use of technology in education were examined. According to teachers, technological educational tools contribute to language and cognitive development, while also increasing students' interest in learning and supporting the permanence of information. This shows that technology is more than just a tool; it can play an active role in pedagogical processes. Especially in early childhood, the use of such tools can help make learning more fun and engaging. examined the effects of science courses conducted through educational digital games on students' knowledge retention, academic achievement, and attitudes. As a result of the research, it was concluded that science courses conducted through educational digital games positively increased the cognitive development levels of students (Agırgol et al., 2022).

Examined the effects of a digital game-based education program on the phonological awareness skills of 60-72-month-old children. The research results revealed that the children in the study group showed a significant improvement in their phonological awareness skills in the pre-test and post-test comparisons. Additionally, according to the post-test results, it was found that the experimental group scored higher than the control group. These findings show that digital game-based educational programs contribute to children's language development and improve phonemic awareness skills (Gole and Temel, 2023).

Emphasized that the use of digital game-based learning in early childhood has increased in recent years. They analyzed 37 articles to determine the effects of the relevant method in childhood. According to the results of the study, it was seen that digital game-based learning can have an active impact on developing children's thinking skills and strengthening their learning processes. These findings demonstrate that digital game-based learning is a potentially powerful tool in early childhood education, supporting cognitive development (Behnamnia et al., 2023).

In their study (Unal and Erbil, Kaya, 2024), they investigated the use of digital games in mathematics education in early childhood. According to the findings of the study, it has been revealed that the integration of digital games and applications into mathematics education contributes to the development of children's mathematical skills. However, in order for these technologies to be implemented effectively, pre-school teachers need to include digital games appropriately in the learning process, take into account children's individual needs and interests, and establish a strong collaboration with parents. Examined studies on the use of digital games in mathematics classes can be found in Turkey by Aydın and Ata (2024). When the instructional features of the studies were evaluated, it was observed that digital game-

based learning generally had positive effects on mathematical achievement and cognitive and affective skills related to mathematics. In addition, the studies examined showed that digital games were mostly used for reinforcement purposes in classes.

According to the results of another study, which investigated the effects of educational mobile games on the critical thinking skills of pre-school children. The results of the study show that integrating educational mobile games into the existing pre-school curriculum improves children's critical thinking skills (Calhan and Goksu, 2024). Digitalization could potentially benefit children's creative and cognitive development, and aimed to examine the effect on a sample of pre-school children. The digital intervention used in the study is a specially designed digitally supported learning program called "Pre-schoolers: Digital Adventures"(Chen and Ding, 2024). The current findings of the study reveal that digital enrichment of the learning process in pre-school education can help improve certain aspects of children's creative-cognitive development. This case shows that digital tools can play a supporting role in education in early childhood.

The Purpose of the Study:

This study proposes to analyze the contributions of digital games to computational thinking and to develop educational materials and digital game-based learning experiences that are appropriate for children's developmental needs. The purposes of this study are as follows:

- To determine how computational development can be supported with digital games in early childhood.
- To examine the effect of providing computational thinking skills in early childhood on children's problem solving, reasoning, and algorithmic thinking abilities.
- To discuss the usability of information technologies and digital games as an educational tool in developing children's computational thinking skills.

The sub-objectives determined in line with these general objectives are presented below:

- Is there a significant difference between the pre-test and post-test achievement test scores of the experimental group?
- Is there a significant difference between the pre-test and post-test achievement test scores of the control group?
- Is there a significant difference between the pre-test achievement test scores of the experimental and control groups?
- Is there a significant difference between the post-test achievement test scores of the experimental and control groups?
- What are the learning outcomes at the end of the 4-week training process?

The Importance of the Study:

This study aims to examine the concurrence of these two topics by addressing the impact of digital games on computational thinking in early childhood. This study draws attention to the need to investigate the role of digital games and computational thinking that can contribute to the cognitive, social, and emotional development processes of children aged 0-6 and to create educational materials suitable for this age group.

It can be said that children's perception of play has changed in parallel with technological developments today. While children used to play with their peers on the streets in the past, today technological devices have become play tools for the children we call Generation Z. Therefore, digital games have become indispensable in children's lives (Bird, 2012; Korkusuz and Karamete, 2013). It is known that digital games have positive and negative effects on children, especially in a critical period such as early childhood. It is seen that digital games are effective in developing hand-eye coordination, focusing attention, and problem-solving skills in children (Kim and Smith, 2017; Lin and Hou, 2016). In addition, it is known that if creative games suitable for children's ages are selected, it can contribute to the development of children's creativity through these games (Arslan and Gorgulu, Arı, 2023).

In this context, it is foreseen that the relevant research will offer an innovative perspective in developing educational materials by drawing attention to the importance of digital game-based learning experiences that develop computational thinking skills of children in early childhood, how they can be integrated into the educational process, and revealing the learning opportunities offered by digital games.

Materials and Methods

This section includes the research model, study group, process steps, structure of groups, data collection tools and data analysis sections.

Research Model

In this study, the fully experimental method, one of the experimental research designs, was used. Experimental studies are studies aimed at testing the effect of the differences created by the researcher on the dependent variable (Buyukozturk et al., 2019). The reason for using experimental research, one of the quantitative research methods, in this study is that it is the most appropriate method for applying digital game applications to a group with defined limits and properties. For this reason, experimental and control groups were randomly created, and a comparison was made after the implementation.

Table 1. *Study groups*

Groups	Girl	Boy
Experimental group	13	12
Control group	12	13

Research Model

This study was conducted with kindergarten students studying in a pre-school institution in Turkey in the 2024 – 2025 academic year. The experimental and control groups in the study consisted of 25 students each. The 50 students (25 girls, 25 boys) included in the study were aged 5.

Sample Method

In this study, the convenience sampling method was selected from the sampling methods. Convenience sampling method is the collection of data from a sample that the researcher can easily reach. For example, the selection of schools that are easy for the researcher to access and permit. The relevant sampling method is a method that accelerates the research. Because in this method, the researcher selects a situation that is close and easy to access (Kılıc, 2017).

Process Steps

Table 2 shows the path followed during the study. The study was carried out in 3 steps: pre-implementation, implementation, and post-implementation.

Table 2. *Process steps*

Process Steps	Preparation Process
Before Implementation	Preparing activity Obtaining permissions to use Rubric Creating an achievement test
Implementation	Conducting pre-tests 4-week implementation process Conducting post-tests
After Implementation	Analyzing data Presenting the findings Determination of learning outcomes

For this study, firstly, the activities and games to be used in the lessons were prepared. Rubric permissions were obtained, and the achievement test was created. Then, the validity and reliability study of the achievement test was carried out. After the preparations of the achievement test were completed,

experimental and control groups were created and pre-tests were applied to the groups. Then the teaching plan was applied to the students who participated in the study. After the application was completed, the post-tests were applied to the students and the data were analyzed and the findings were presented.

In this study, a 4-week training activity was conducted on experimental and control groups to develop the computational thinking skills of 5-year-old pre-school children. The aim of the study was to children understand the commands of going forward-backward, turning right and turning left through activities using Bee Bot, paper activities and digital games. With Bee Bot (https://www.robokids.com.tr/bee-bot-okul-oncesi-programlama-robotu), paper activities and digital games were designed by researchers in accordance with the applications themed around shapes and colors. The designed activities and games were restructured after being submitted to expert opinion, and necessary revisions were made. The students participating in the study had not been taught algorithms or coding before. Students from two different classes were randomly selected as one class control group and the other class experimental group. During the 4-week study, the educational activities applied to both groups were differentiated, and in this context, student development was measured with rubric evaluations made by two different computer teachers. The cognitive development of the 5-year-old students who made up the study group was tested through observation by the course teachers. Observation is mostly used as a way to easily reveal behavioral changes in children and to understand and detail this behavior. It is also a way to predict behavior in advance.

Structure of Groups

Experimental Group: The group consisting of 5-year-old children who have not taken a coding course and who received Bee Bot training supported by digital games.

Control Group: A group of 5-year-old children who had not taken a coding course and received Bee Bot training through paper activities.

The planned activities for the groups are shown in Table 3-Table 3.1. below.

Table 3. *Experimental group study plan*

Weeks	Activities
Week 1	Getting to know Bee Bot
Week 2	Basic forward-backward, turn right-turn left command exercises with Bee Bot. Activity practices, achievement test (pre), and rubric pre-test.
Week 3	Digital Game-1 Digital Game 2 Applications.
Week 4	Achievement test (post), rubric post-test, determination of teaching outcomes

Table 3.1. *Control group study plan*

Weeks	**Activities**
Week 1	Getting to know Bee Bot
Week 2	Basic forward-backward, turn right-turn left command exercises with Bee Bot. Activity practices, achievement test (pre) and rubric pre-test.
Week 3	Paper activity 1-2, Paper activity 3-4.
Week 4	Achievement test (post), rubric post-test, determination of teaching outcomes

Experimental group activities: Includes digital game activities in addition to Bee Bot.

Control group activities: Includes Bee Bot apps and paper activities. Bee Bot applications were used to teach the same commands to both groups. The inclusion of digital games in addition to the experimental group was done to observe the effect of digital games on computational thinking skills.

Data Collection Tools

The achievement test prepared for the cognitive domain consists of 15 multiple-choice questions prepared for target achievements to be used as a pre-test and post-test. In the preparation of the achievement test, expert opinions were taken from 3 faculty members, who teach in the Pre-School Education Department of the Basic Education Department. Following the expert opinion received, expert faculty members confirmed that the achievement test was suitable for the relevant teaching level. It has been

recommended by expert faculty members that the questions be read to pre-school students by assistant teachers and their answers be obtained.

With the Ladybug U bot coding tool supported by digital games and paper activities used throughout the 4-week teaching period, children were taught game-supported and paper activity topics and commands such as algorithm creation, sequencing, function creation, loops, and debugging. The questions developed for the achievement test were prepared to measure the learning of these topics and commands. While developing the achievement test, the process applied by Seker and Gencdogan (2014) for the achievement test was taken into consideration. The procedures carried out in this direction are presented below:

a) Determining the scope: The purpose of the test is to determine the readiness level of the students in the experimental and control groups.

b) Determination of targets/learning outcomes: The learning outcomes are within the scope specified in the pre-school curriculum. In this direction, there are 5 basic achievements expected to be achieved in the unit.

c) Creation of evaluation rubrics: A rubric sample developed by the researchers was used to evaluate student performances with various criteria.

d) Preparation of test questions: Expert opinion was obtained on the item pool created based on the achievements, and it was decided to prepare multiple-choice questions. A question pool of 23 items was created.

e) Test implementation/scoring: In line with the opinions received from a program developer, a measurement & evaluation and a field expert, 3 questions in the item pool were removed, and it was decided to apply 20 questions as is.

f) Implementation of the test, validity and reliability study: The achievement test, consisting of 5 achievements and 15 items, was applied to the experimental and control groups of 50 people, and KR-20 was calculated for reliability.

Performing item analysis: The highest score that can be obtained from the test was determined as 20, the lowest score as 0. Each question was determined as 5 points. As a result of the analysis of the answers given to the test, the item difficulty index (p) and the item discrimination index (D) were calculated. Accordingly, at least one question remained that measured each gain.

Kuder Richardson-20 was used in reliability analysis because of the coding of right and wrong answers as 1 and 0 while developing the achievement test. In the item difficulty index calculated using the formulas shown in Table 4, .20 to .00: very difficult; .21 to .40: difficult; .41 to .60: medium difficulty; .61 to .80: easy; .81 to 1.00: very easy. In item discrimination values, items with values below .20 were removed from the test.

Table 4. *Scores regarding the analysis of the test*

Question	Item Difficulty Index (p)	Item Discrimination Index (D)
Q1	.62	.30
Q2	.70	.21
Q3	.65	.30
Q4	.66	.34
Q5	.69	.30
Q6	.66	.30
Q7	.60	.31
Q8	.67	.33
Q9	.63	.36
Q10	.59	.31
Q11	.59	.30
Q12	.56	.34
Q13	.59	.30
Q14	.62	.31
Q15	.58	.30
Q16	.46	.28
Q17	.73	.31
Q18	.65	.36
Q19	.73	.31
Q20	.83	.21

According to Table 4.1; an achievement test consisting of 20 items was developed by the researchers in order for students to comprehend the relevant structures. The KR-20 reliability of the test was found to be 0.84. Getting a high score from the test shows that the level of achievement of the gains is high. KR-20 value of 0.80 or greater is desirable. However, 0.70 and above is also acceptable. Scales with KR-20 value of less than 0.70 are not good enough (Shepard, 2005).

Creation of Evaluation Rubrics

Rubrics are usually in the form of tables based on horizontal and vertical axes. The vertical axis usually contains performance criteria, and the horizontal axis contains increasing performance levels from the lowest level to the highest level. At the intersection of the horizontal and vertical axes, there are performance definitions related to the performance level of the performance criterion. Performance criteria allow the components of performance to be seen.

Table 5. *Evaluation rubric*

	Excellent(6)	Very good(5)	Good(4)	Average(3)	Limited(2)	Very limited(1)
Analysis	Separate a problem into smaller parts accurately, precisely and confidently. Explains the problem systematically	Properly separate the problem into smaller pieces	Separates the problem into smaller pieces with minor mistakes	Separates the problem into smaller pieces with significant mistakes	Separates the problem into smaller pieces with the teacher's guidance	Shows no evidence of analysis.
Pattern recognition	Recognizes patterns accurately and reliably, making accurate predictions based on pattern variations	Recognizes patterns accurately	Recognizes patterns with minor mistakes	Recognizes patterns with major mistakes	Recognizes patterns under the guidance of the teacher	Shows no evidence of pattern recognition.
Abstraction	Simplifies a problem, identifies main ideas accurately and confidently, and explains the most important details of the problem	Simplifies a problem and identifies main ideas accurately	Simplifies a problem and identifies main ideas with minor mistakes	Simplifies a problem and identifies main ideas with significant mistakes	Simplifies a problem and identifies main ideas with teacher guidance	Does not show any evidence of abstraction.
Algorithm design	Creates a logical sequence of steps, solves a problem accurately, effectively, and safely, and can explain procedures in detail	Creates a logical sequence of steps to correctly solve a problem	Creates a logical sequence of steps to solve a problem with minor mistakes	Creates a logical sequence of steps to solve a problem with major mistakes	Creates a logical sequence of steps to solve a problem with teacher guidance	Shows no evidence of the algorithm.
Logical reasoning	Correctly predicts the logical facts of a problem	Accurately determines the logical facts of a problem	Guessing the logical truths of a question with small mistakes	Guessing the logical truths of a problem with major mistakes	Guess the logical truths of a problem under the guidance of the teacher	Provides no evidence of logical truths.
Evaluation	Evaluates solutions, identifies any mistakes, successfully fixes them and suggests improvements	Evaluates solutions, identifies and corrects any mistakes	Evaluates solutions, identifies most mistakes and successfully fixes them	Evaluates solutions, identifies and corrects some of the mistakes	Evaluates solutions under teacher guidance	Shows no evidence of evaluation.

Rubrics are scoring scales developed by teachers or other assessment professionals to guide students in their learning process or to help them understand how to analyze learning products and thus

support their learning (Mertler, 2001; Truemper, 2004; Moskal, 2000; Shepard, 2005). According to the table above a rubric sample developed by the researchers was used to evaluate student performances with various criteria. The success criteria in the relevant rubric were observed and scored by two computer teachers throughout the teaching-learning process. Rubric criteria are structured according to the computational thinking approach developed by the (Panadero and Jönsson, 2013).

Analysis of Data

In cases where there are fewer than 30 participants in the experimental and control groups, it is difficult to assume that the scores are normally distributed. In such cases, it is appropriate to use non-parametric tests for analysis (Buyukozturk et al., 2011). Wilcoxon Signed Rank Test and Mann-Whitney U-Test were used in the analysis of the data because the number of groups was small and the distribution did not show normality.

Results

Comparison of the experimental groups and the control group separately according to their scores before and after the training was made using Kruskal-Wallis and Mann-Whitney U non-parametric tests, as the data did not show a normal distribution. Since p<0.5 was obtained within the scope of the Kolmogorov-Smirnov test, it was accepted that the data did not show a normal distribution. The general average was taken into account in explaining the differences in the data. The findings obtained in the study are presented below through the relevant tables.

Comparison of Achievement Tests of Experimental and Control Groups:

Comparison of achievement tests of experimental and control groups was made using the Mann-Whitney U test. The Mann-Whitney U-test can be used when the aim is to show the difference in the value of an ordinal, interval, or proportional variable between two groups.

Table 6. *Comparison of Pre-Test Success Scores of Experimental and Control Groups: Mann-Whitney U Test Result*

Groups	N	Average Rank	Total Rank	U	p	Significant Difference
Experimental Groups	25	57.10	3426	1596	.281	There is no significant difference between the groups
Control Groups	25	63.90	3834			

According to the table, since the p value is .281> .05, there is no significant difference between the pre-test success scores of the experimental group and the control group.

Table 6.1. *Comparison of Post-Test Success Scores of Experimental and Control Groups: Mann-Whitney U Test Result*

Groups	N	Average Rank	Total Rank	U	p	Significant Difference
Experimental Groups	25	67.68	4061	1369	.004	There is a significant difference between the groups
Control Groups	25	53.32	3199			

According to the table, since the p-value is .004 < .05, there is a significant difference between the post-test success scores of the experimental group and the control group, and this difference is in favor of the experimental group.

Experimental Group Pre-Test & Post-Test Achievement Test:

Table 6.2. *Wilcoxon signed rank test results of achievement test scores before and after the experimental group*

Groups	Pretest-Post test	N	Average Rank	Total Rank	Z	P	Significant Difference
Experimental Group	Negative Orders	1	.00	.00	-6.736	.000	There is a significant difference between the groups
	Positive Orders	24	30.25	1830.0			
	Equal	0					

Pre-test and post-test achievement test scores of the experimental group students were tested with the Wilcoxon signed-rank test. According to Table 6.2, the learning outcomes of the experimental group

students participating in the study were examined. In this context, the Wilcoxon Signed Rank Test was used to determine the significant difference between the pre-test and post-test academic achievement scores. When the academic achievement scores of the experimental group students were compared to the relevant test, a significant difference was found in favor of the post-test (z=-6.736; p<.05).

Table 6.3. *Wilcoxon signed rank test results of achievement test scores before and after the control group*

Groups	Pretest-Post test	N	Average Rank	Total Rank	Z	P	Significant Difference
Experimental Group	Negative Orders	1	4.88	19.5	-6.593	.000	There is a significant difference between the groups
	Positive Orders	24	32.33	1810.5			
	Equal	0					

According to Table 6.3, the learning outcomes of the control group students participating in the study were examined. In this context, the Wilcoxon Signed Rank Test was used to determine the significant difference between the pre-test and post-test academic achievement scores. Accordingly, when the academic achievement scores of the control group students were compared with the relevant test, a significant difference was found in favor of the post-test (z=-6.593; p<.05).

Evaluation Rubric Analysis:

The responses from 50 students to the relevant rubric developed by Panadero and Jönsson (2013) were analyzed and delivered to 2 computer teachers. In addition, teachers were given a graded scoring key and a scoring table with student names. Teachers first graded the problems without using a scoring rubric. Each question is worth 15 points in the evaluation. Since there are 6 problems, a student who answers all of them correctly will receive a total of 90 points, and the student with the lowest score will receive a total score of 0. The scores made by the teachers without using the rubric were collected. The same teachers scored the same papers with the rubric, and they did these scores 2 weeks later to reduce the memory effect. The consistency between the scores given by the teachers to the student answers using the graded scoring key was examined separately for the 1st-6th problems.

Table 7. *Correspondence between the scores given by teachers to student responses using a rubric*

	N	Kendall w	Sd	p
1. Problem	50	.85	26	.000
2. Problem	50	.83	26	.000
3. Problem	50	.82	26	.000
4. Problem	50	.83	26	.000
5. Problem	50	.81	26	.000
6. Problem	50	.82	26	.000

When Table 4-1 is examined, the Kendall w result between the scores given by 50 raters to the student answers using the rubric was found to be .85 for problem 1, .83 for problem 2, .82 for problem 3, .83 for problem 4, .81 for problem 5, and .82 for problem 6. These values show that there is a high consistency between the scores given by the teachers using the rubric for each problem. Since the Kendall W test is a test used to evaluate the compatibility of raters, it can be said that the consistency between the separate scores of the teachers for each question is at a high level. Although the Kendall w coefficients of all 6 problems are close to each other, it is seen that the highest consistency is in problem (Buyukozturk et al., 2011).

Discussion

In their research, Pan et al. (2024) studied improving the computational thinking competence of secondary school students through game-based learning. The findings of the study confirmed that game experience positively affected students' computational thinking self-efficacy, but did not affect their game-based engagement. When comparing the demographic factors of age (grade) and previous gaming experience, it was found that the gender factor tended to play a more important role in students' self-efficacy

regarding computational thinking competence and in the extent to which it moderated game-based participation. At the end of the study, implications and possible directions for future research on using game-based learning to improve computational thinking competence are discussed.

According to the results of another study, researchers studied middle school students on the subject of computational thinking through game design and contributed a case study to the literature in the relevant field. This study used Code.org's block-based programming curriculum and evaluated its impact on middle school students' Computer Technology (CT) skills and attitudes toward CT and CS (Computational Science). The findings of the study proved that the participants showed a significant increase in algorithmic thinking, debugging, and pattern recognition skills, but not in abstraction skills (Cafarella and Vasconcelos, 2024).

In their study, Cheng et al. (2023) examined the development of computational thinking skills throughout program question strategies in a game-based learning platform. The study group consisted of 53 primary school students, and the data were collected during four lesson hours consisting of experimental Computational Thinking (CT) activities. This study shows that the experimental group using the student-generated questions (SGQ) strategy with the game-based learning (GBL) platform exhibited significantly higher information technology (IT) skills than the control group.

Conclusion and Recommendation

This study proposes to analyze the contributions of digital games to computational thinking and to develop educational materials and digital game-based learning experiences that are appropriate for children's developmental needs. This study was conducted with kindergarten students studying in a pre-school institution in Turkey in the 2024 – 2025 academic year. The experimental and control groups in the study consisted of 25 students each. The 50 students (25 girls, 25 boys) included in the study were aged 5. Within the scope of relevant purposes, a 4-week training activity was conducted on experimental and control groups to develop the computational thinking skills of 5-year-old pre-school children. The study aimed to help children understand the commands of going forward-backward, turning right and turning left through activities using Bee Bot, paper activities, and digital games. With Bee Bot, paper activities and digital games were designed by researchers in accordance with the applications themed around shapes and colors. The designed activities and games were restructured after being submitted to expert opinion, and necessary revisions were made. The students participating in the study had not been taught algorithms or coding before. Students from two different classes were randomly selected as one class control group and the other class experimental group. During the 4-week study, the educational activities applied to both groups were differentiated, and in this context, student development was measured with rubric evaluations made by two different computer teachers.

In this study, the fully experimental method, one of the experimental research designs, was used. In cases where there are fewer than 30 participants in the experimental and control groups, it is difficult to assume that the scores are normally distributed. Non-parametric tests were preferred in the analysis of data because the number of groups was small and the distribution did not show normality. The test results for the sub-objectives determined in the research are presented below:

There is a significant difference between the pre-test and post-test academic achievement scores of the experimental group participating in the program regarding the course outcomes. A significant difference was found in favor of the post-test in terms of achievement scores. There is a significant difference between the pre-test and post-test academic achievement scores of the experimental group participating in the program regarding the course outcomes, and no significant difference was found in favor of the post-test in terms of academic achievement scores. According to the results of the Mann-Whitney Test conducted to compare the pre-test and post-test achievement tests of the experimental and control groups, there is no significant difference between the pre-test success scores of the experimental group and the control group. There is a significant difference between the post-test success scores of the experimental group and the control group, and this difference is in favor of the experimental group.

The responses from 50 students to the relevant rubric developed by the researchers were analyzed and delivered to 2 computer teachers. In addition, teachers were given a graded scoring key and a scoring table with student names. Each question is worth 15 points in the evaluation. Since there are 6 problems, a student who answers all of them correctly will receive a total of 90 points, and the student with the lowest score will receive a total score of 0. The consistency between the scores given by the teachers

to the student answers using the graded scoring key was examined separately for the 1st-6th problems. the Kendall W result between the scores given by 50 raters to the student answers using the rubric was found to be .85 for problem 1, .83 for problem 2, .82 for problem 3, .83 for problem 4, .81 for problem 5, and .82 for problem 6. These values show that there is a high consistency between the scores given by the teachers using the rubric for each problem.

Within the scope of the study, the following suggestions are presented for future research and researchers:

- This study was conducted with kindergarten students studying in a pre-school institution in Turkey in the 2024 – 2025 academic year. In order to obtain different and/or similar results within the scope of the situation, the same research can be repeated by different researchers, in different educational environments and with different study groups.
- Studies can be conducted in educational institutions to determine to what extent students are informed about the theory, application, and evaluation methods of the computational thinking approach or to what extent the relevant approach is adopted by students.
- It is recommended that similar research be conducted by updating the learning content and materials in line with the developments in the field.

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Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, Ayse ALKAN; methodology, Ezgi Pelin YILDIZ; software, Murat TEZER; validation, Ezgi Pelin YILDIZ, Ayse ALKAN & Murat TEZER; formal analysis, Ezgi Pelin YILDIZ; research, Ayse ALKAN; resources, Murat TEZER; data curation, Ezgi Pelin YILDIZ; writing - review & editing, Ezgi Pelin YILDIZ; visualization, Murat TEZER; supervision, Ezgi Pelin YILDIZ, Ayse ALKAN & Murat TEZER; project administration, Ezgi Pelin YILDIZ. The authors read the final version of the article together and decided to publish together.

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Attitudes of Students and Teachers' Opinions Towards Robotic Applications in Secondary Schools

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Abstract: The ongoing advancements in technology and their implications for robotics raise questions regarding high school students' attitudes toward robotic applications. The formation of teachers' opinions is identified as a research gap alongside these developments. This research aims to measure the attitudes of students in secondary schools towards robotic applications, in terms of various variables and to evaluate teachers' opinions. This research was designed as mixed methods research. The sample of the research consisted of 469 students and 25 teachers. The quantitative data of the study were collected with the robotics activity attitudes scale-RAAS, which was adapted to the language of the researchers. Qualitative data was collected with the teacher interview form created by the researchers. Parametric tests, t-tests, and ANOVA were applied to the data set, and weighted average, frequency, and percentage calculations were made. The data obtained from the teacher interview form was transformed into findings using the descriptive analysis method. As a result of the research, it was determined that the students had a high degree of robotic attitude. It was determined that students' robotic attitudes showed a significant difference in favor of male students according to the gender variable. There was no difference in students' robotic attitudes depending on the classroom variable, and a majority of teachers have a positive attitude towards the use of robotic applications in education in Kazakh secondary schools. The attitudes and opinions of teachers and students towards robotic applications are positive.

Keywords: *attitude, robotic applications, robotic attitude scale, secondary schools.*

Introduction

The perceived advantages of robotic applications in secondary education have been the subject of numerous research, which have led to favorable attitudes among instructors and students. A substantial amount of research highlights how educational robots increases student engagement and motivation, especially in STEM education. According to Selcuk at el. (2024), integrating robotics into the curriculum increased students' interest in it and created a more dynamic and engaging learning environment. This dedication is essential because increasing academic performance is directly related to intrinsic motivation, especially in subjects that find it difficult to pique students' interest.

Additionally, the development of pupils' computational thinking abilities has been linked to the use of robotics in the classroom. According to Zhang at el. (2021), students' views about STEM areas are reshaped by robotics exposure, which also helps them develop their problem-solving abilities. Given the current emphasis on developing the abilities required for the landscape facilitated by the technology of the future workforce, this transition is essential. Teachers can better prepare students for postsecondary education and careers in STEM fields by utilizing robotics, which helps close the skills gap in a number of industries.

Teachers have also realized how robotic applications can offer experiential learning possibilities tailored to the needs of various students. According to Di Battista, et al. (2020), robots can specifically help kids with special education needs by offering engaging and dynamic learning opportunities that were previ-

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ously challenging to accomplish. Because robotic technologies may bridge learning gaps and establish fair learning environments where all students can thrive, their versatility emphasizes the inclusion they offer.

It has also drawn attention to how enthusiastic teachers are about incorporating robotics into their lesson plans. According to the study, educators are becoming more interested in integrating technology into their lessons as they become aware of the educational benefits of robots (Piedade, 2021). Given that robotics not only enhances student learning but also acts as a catalyst for teacher professional development, this increased interest is indicative of a larger trend towards the modernization of educational processes. Teachers frequently express their desire to employ these cutting-edge tools to enhance their technical proficiency and pedagogical approaches, which will further enhance the teaching and learning environment.

Nevertheless, even while robotic applications are thought to have significant advantages in terms of encouraging student engagement and enhancing teaching methods, it is crucial to investigate the difficulties that accompany their use. A more thorough grasp of the advantages and disadvantages will result in a more complete picture of how robots affects the educational landscape. While there are many benefits to using robotic applications in secondary schools, there are also a number of drawbacks that can have a big impact on instructors' and students' views. The difficulty of learning and utilizing robotic technology is a common issue in the literature. According to Ortega-Ruiperez and Alcalde (2023), some students view programming as a daunting undertaking requiring a certain set of technical skills. This can deter students from participating in robotics-related activities. This sentiment highlights the necessity for educators to address the robotics learning curve because programming anxiety can lead to a lack of interest in STEM (science, technology, engineering, and mathematics) subjects.

According to the teachers, the difficulties go beyond the pupils' participation and encompass feelings of inadequacy over their own robotics skills. According to Papadakis and Kalogiannakis (2020), a lot of teachers are intimidated by their ignorance, which can make them hesitant to include robotic applications in their lessons. The rapid advancement of technology exacerbates this lack of confidence by causing a gap between instructors' present skill levels and the requirements of modern educational tools. As a result, the positive benefits that robotics can have on the classroom may be hampered because children might not receive enough help or direction from teachers who feel unprepared.

Furthermore, Kucuk and Sisman's (2020) study revealed notable differences in students' openness to robotic applications according to variables including gender and prior exposure to related technology. According to their research, male students are more likely than female students to be confident and enthusiastic about participating in robotics, which can help them overcome emotions of intimidation or disinterest. In order to foster a more equitable learning environment, educational interventions should be modified to account for these inequalities and guarantee that all students are included and actively participate (Sahmurova, and Gursesli, 2020).

Teachers' perspectives of the tools and training required for the successful integration of robots in the classroom add another level of complication. According to Negrini (2020), teachers are generally skeptical about the feasibility of incorporating robotic applications in the absence of sufficient institutional support. Teachers frequently voice worries about a lack of resources, such as funding, workshops for training, and necessary access to technology. This concern suggests that while educators acknowledge the potential educational advantages of robotics-such as the ability to foster critical thinking and problem-solving abilities-they also acknowledge the logistical obstacles that may jeopardize these prospects.

The combination of these elements implies that although everyone agrees that robotic applications have the potential to improve educational outcomes, students and teachers should overcome a number of obstacles that may make implementation more difficult. Promoting positive attitudes and optimizing the impact of robotics in high school will require addressing these issues through focused training, resource allocation, and the development of an inclusive learning environment. The use of robotics in secondary education has generated a lot of discussion and exposed a variety of attitudes in both instructors and students. The efficacy and sustainability of robotics in the educational environment are largely determined by these attitudes, which are influenced by both individual experiences and institutional environments. Students' increased devotion to robotics applications is a common benefit, as seen by their enthusiastic engagement in robotics camps and project-based learning activities. Such stimulating activities can significantly boost pupils in STEM subjects, fostering a generation of people who want to pursue careers in science, technology, engineering, and mathematics, according to research by Üçgül, and Altıok, (2022) and Tiryaki and Adigüzel (2021). When robotics is included into the curriculum, students frequently report

feeling more motivated and interested in learning. This shows that robotics applications act as both instructional tools and catalysts to ignite a passion for technical materials.

On the other side of the spectrum, students' excitement is contrasted with educators' worries about the long-term viability of robotic projects. Without a specific framework to guarantee their integration into the larger study program, Diken (2022) contends that the mere deployment of robotic technology is inadequate and emphasizes the necessity of ongoing support and resources. In order to use robotic applications effectively, teachers raise concerns about the resources' accessibility, which necessitates the availability of current professional development opportunities. This demonstrates the differences in preparation and resource availability, which affect teachers' willingness to use robots in their lessons generally.

Furthermore, a significant body of literature offers a nuanced viewpoint on the overall effects of robotic applications in the classroom. Although numerous research point to observable benefits including enhanced teamwork and innovative problem-solving abilities (Zadok, 2020), these benefits need to be considered in the context of implementation difficulties. The potential benefits of robotics in education can be hampered by a number of issues, according to educators, including varying levels of institutional support, insufficient training, and financial limitations. Understanding these difficulties is crucial because it draws attention to the intricate realities that instructors must deal with while implementing new technologies.

In their research, Zhong and Xia (2020) conducted a systematic review to explore the potential of educational robotics in mathematics education. In their research, Zviel-Girshin and Shaham (2020) evaluated robotic applications as a tool to develop technological thinking in early childhood. Di Battista, et al. (2020) consulted teachers' opinions on the effectiveness of robotic applications in education, and as a result of the research, teachers stated that robotic applications were effective for students with special needs. Lebrasseur at el. (2021) used various robotic arms in their studies and revealed that children showed significant improvements in performing their daily activities. Boyarinov and Samarina (2020) organized an educational robotics course for teacher candidates as a research subject. MägiMägi, at el. (2021), discussed the effectiveness of using robotic toys in early childhood education to support children's social and emotional competence. In their research, Boada Maestre and Genís (2021) evaluated ethical issues in the use and integration of educational robots in special education. In their research, Kanbul and Uzunboylu (2017) evaluated the effectiveness of coding training and robotic applications in acquiring 21st-century.

Despite teachers' concerns, research shows that there is a general sense of cautious optimism regarding the use of robotics in the classroom. Concepts gathered from numerous studies indicate that the use of robotic applications can result in a rich, multifaceted educational experience when schools offer the required skills and infrastructure. The next generation of well-documented issues and the assurance that educators and students feel prepared to interact with robotic technologies are prerequisites for this hopeful outlook.

Today, the work done in the 21st century for students, teachers and educational programs, which are expressed as the three basic elements of education, are more valuable than in previous periods. Research in the field evaluates the application of robotics in education at different levels and in different areas of education. However, with the technological developments that are developing every day, with their reflections on the field of robotics, there is still a question about the attitude of high school students towards robotic applications. In parallel with these developments, we wonder how teachers' opinions are formed. It is very important that these issues are presented as a research gap.

Purpose of the Research

The purpose of this research is to measure the attitudes of students in secondary schools toward robotic applications in terms of various variables and to evaluate teachers' opinions. Following the research purpose, the following hypotheses and research questions were developed.

H_1: Students in secondary schools have high attitudes towards robotic applications.

H_2: The attitudes of students in secondary schools towards robotic applications differ according to gender.

H_3: The attitudes of students in secondary schools towards robotic applications vary depending on the class they study in.

1. What are the teachers' opinions about the use of robotic applications in education in secondary schools?
2. What are teachers' opinions about the advantages of using robotic applications in education?
3. What are teachers' opinions about the disadvantages of using robotic applications in education?

4. What are teachers' suggestions for increasing the use of robotic applications in education?

Materials and Methods

This section contains information about the research method, study group, development of the data collection tool, collection and evaluation of data, and the ethical process of the research.

Research method

This research was designed as mixed methods research. Mixed method research design is a design in which qualitative and quantitative data are collected and both designs are considered together. The aim of this design, where two designs are used in a single study, is to allow a more detailed and comprehensive understanding of a phenomenon by using the advantages of qualitative and quantitative data (Sahmurova, at el. 2010; Sandelowski, 2000; Sezgin, at el. 2019). In this study, a mixed method design was preferred to measure the attitudes of students in Kazakh secondary schools towards robotic applications in terms of various variables and to evaluate teachers' opinions.

Participants

In this research, simple sampling technique is used. Simple random sampling is a technique in which each element in the population has equal chance and probability of being selected. Here, the selection of elements depends entirely on chance or probability; therefore, this sampling technique is sometimes known as chance method. Simple random sampling is a basic sampling method and can easily be a component of a more complex sampling method. The main feature of this sampling method is that each sample has the same probability of being selected.

The quantitative sample group of the research consists of 469 students studying in various secondary schools in Kazakhstan in the 2024-2025 academic year. Likewise, simple sampling technique was used to determine the sample group in collecting qualitative data. The qualitative sample group includes 25 teachers working in various secondary schools in Kazakhstan in the 2024-2025 academic year. Demographic information about students and teachers is given in Table 1.

Table 1. *Demographic information of students and teachers.*

Student		
Gender	F	%
Female	211	44.9
Male	258	55.1
Class	F	%
9th grade	138	29.4
10th grade	142	30.3
11th grade	189	40.3
Total	469	100
Teacher		
Gender	F	%
Woman	11	44
Male	14	56
Total	25	100

Table 1 shows the demographic distribution of the students and teachers who participated in the research. 44.9% of the students are female and 55.1% are male. 29.4% of the students participating in the research are studying in the 10th grade, 30.3% are in the 11th grade and 40.3% are in the 12th grade. 44% of the teachers participating in the research are women and 56% are men.

Data collection tools

The quantitative data of the study were collected with the robotics activity attitudes scale-RAAS (Cross, et al. 2016), which was adapted to the language of the researchers. In the qualitative part of the research, a teacher semi-structured interview form was developed by the researchers to evaluate teachers' opinions. The translated items were arranged in line with the opinions of experts and a temporary scale form was created.

Robotics attitude scale

The original form of the scale was developed by Cross et al. (2016) The scale has a structure of 45 items and consists of 4 factors. The factors of the scale were determined as curiosity, interest, expectation, trust, and identity. The Cronbach Alpha internal consistency coefficient of the scale was found to be 0.972.

Language Equivalence Study: The Robotic Attitude Scale form, which will be adapted into Kazakh, was translated into Kazakh by 4 experts working in the field of linguistics who know both languages very well. These translations were examined, taking into account expert suggestions, and a temporary Kazakh form was created. It is intended that there will be no difference in meaning between the translation and the original form. For this reason, the created Kazakh form was translated back into the original language by experts using the back-translation method after 3 weeks. The Kazakh translation was compared with the original scale, and the final version of the scale in Kazakh was created with the closest translations.

Pilot application: At this stage, the pilot application sample group of the scale was created and the draft scale was applied to the sample group. 453 secondary school students participated in this part of the research. 204 of the students are girls and 249 are boys. The students who participated in this part of the research were not included in the main sample group of the research. 453 students met the sample size criterion of 5 times the number of items required in factor analysis studies (Child, 2006).

Exploratory Factor Analysis: At this stage, the SPSS 25.0 statistical program was used. In the first stage, it was checked whether the adapted scale had a normal distribution. Kolmogorov-Smirnov was preferred as the normal distribution test. As a result of the application, the analysis made on the data set ($p=.052>.050$) indicates a normal distribution. All items in the scale were used for exploratory factor analysis. In this analysis, it was first aimed to test whether the sample size was sufficient. The value of $0.76 > 0.70$ obtained from the Kaiser-Meyer-Olkin (KMO) test revealed that exploratory factor analysis could be performed on the data. Then, Bartlett's Sphericity test was applied and the results were evaluated. Bartlett's Sphericity test ($\chi^2 =559.677$, $p=.000$) showed that it was appropriate to perform exploratory factor analysis on the data. At this stage, the eigenvalue was determined as 1, and principal component analysis was performed. As a result of the analysis, a structure with 4 factors with an eigenvalue greater than 1 emerged. 13 items that could not be combined under factor structures and pointed to a different factor on their own were removed from the scale. Then the analyses were repeated. As a result of repeated analyses, similar stages were passed and the 24-item structure of the final form emerged. When the scree plot was examined in the exploratory factor analysis, it was determined that the lowest load value was 0.575.

Confirmatory Factor Analysis: At this stage, the SPSS Amos 25.0 statistical program was used. Goodness-of-fit indices were examined for confirmatory factor analysis. χ^2 /df (Chi-Square/Degree of Freedom), NNFI (Non-Normed Fit Index), and RMSEA (Root Mean Square Error of Approximation) values were taken as criteria for the fit of the model. In the analysis, these values are χ^2 /df= 1.354 ($p=.000$), NNFI=.88, and RMSEA=.058, respectively. Hooper et al. (2013) set the value below 5 for χ^2 /df; They recommended above .80 for NNFI and below .080 for RMSEA. Based on this view, it has been revealed that the scale maintains its original structure in Kazakh culture.

The item factor loadings and Cronbach's Alpha coefficients of the scale, which were finalized as a result of confirmatory factor analysis, are given in Table 2.

Table 2. *Robotics attitude scale item factor loadings*

Factor	Item	Expression on Scale	Item Total Correlation	Cronbach's Alpha
Desire to Learn	1	I would like to learn more about robotics	.681	.792
	2	I enjoy learning new information about robots.	.622	
	3	I enjoy doing robotics activities	.615	
	4	I know I can learn a lot about robots.	.641	
	5	I research as much information about robots as I can.	.639	
	6	Learning about robots is important to me.	.674	
	7	I like watching TV shows and/or reading books about robots.	.621	
	8	I'm interested in discovering things about robots.	.655	
	9	Even if it's complicated, I'd love to learn everything about robotics.	.626	
	10	I enjoy exploring new ideas about robotics.	.664	
	11	Robotics interests me.	.648	
	12	I'm curious about how robots work	.645	
Confidence	13	I am a person who can be an expert in the field of robotics.	.588	.866
	14	I can write a computer program.	.592	
	15	I can program a robot.	.603	
	16	I am confident in my ability to build robots.	.583	
	17	I'm good at making robots.	.575	
	18	I can build a robot.	.579	
Computational Thinking	19	I'm good at thinking logically	.720	.812
	20	I like solving complex problems.	.718	
	21	I solve problems logically.	.733	
Team work	22	I can convey my ideas to my group.	.786	.823
	23	I am a good group member	.815	
	24	I enjoy working in groups.	.792	
		Cronbach's Alpha for the Whole Scale		.816

In Table 2, the item totals and Cronbach's Alpha of the robotic attitude view are given as a basis to disseminate the language for the collection of research. In the reliability analysis of the 4-factor structure of the scale, the Cronbach's Alpha value of the desire to learn sub-dimension was found to be 0.792, the Cronbach's Alpha value of the self-confidence sub-dimension was 0.866, the Cronbach's Alpha value of the computational thinking sub-dimension was 0.812 and the Cronbach's Alpha value of the teamwork sub-dimension was 0.823. Cronbach's Alpha value for the overall robotic attitude scale was found to be 0.816. The scale is a 5-point Likert type. In this rating scale, score ranges are considered equal. According to this; the Range from 1.00 to 1.80 Strongly Disagree; 1.81 to 2.60 range Disagree; 2.61 to 3.40 range Partially Agree; The range of 3.41 to 4.20 is rated Agree and the range 4.21 to 5.00 is rated as Strongly agree.

Teacher interview form

A literature review was conducted during the preparation of the teacher interview form. Then, the questions created for the interviews with the teachers were presented to the opinions of 3 field experts. The questions were rearranged in line with expert opinions and asked to 2 secondary school teachers. At this stage, it was evaluated whether there were any unclear points in the questions. The questions, which were stated to have semantic validity by the teachers, were arranged in a semi-structured interview form format and made ready for application. The questions in the teacher interview form are given below.

1. What are your views on the use of robotic applications in education in Kazakh secondary schools? Evaluate by choosing one of the Positive, Undecided, or Negative categories.
2. What are your views on the advantages of using robotic applications in education?
3. What are your views on the disadvantages of using robotic applications in education?
4. What are your suggestions for increasing the use of robotic applications in education?

Data collection process

The quantitative data of the research were collected by applying the robotics attitude scale to teachers via Google Forms. Teacher interview form data was collected through face-to-face interviews with teachers. The robotic attitude scale application time was determined as approximately 20-25 minutes. The average duration of the teacher interview form application was determined as 20 minutes. The language adaptation phase implementation phase of the scale and the implementation phases of the interview forms were completed in approximately 2 months.

Ethics

At each stage of the research, a signed declaration form was received from the teachers and students who participated in the research, declaring their voluntary participation. To researchers; A form was prepared and delivered regarding the method, purpose of application of the research, process, and ethical principles regarding the use of data. Teachers and students who voluntarily agreed to participate in the research by reading the information in the consent form were included in the research. In addition, the principles of research and publication ethics were followed in all processes during which the research was conducted.

Data analysis

In the scale adaptation phase of the research, SPSS 25.0 was used for exploratory factor analysis and SPSS Amos 25.0 was used for confirmatory factor analysis. SPSS 25.0 statistical program was used to analyze the research data. To evaluate normal distribution, Kolmogorow-Smirnov test results were examined and ($p < 0.05$) it was seen that the data set was normally distributed. Parametric tests were performed on the data set obtained from the robotics attitude scale. Independent samples t-test was used in the analysis of bivariate data, and ANOVA, weighted average, frequency, and percentage calculations were used in the analysis of more than two variable data. Descriptive analysis technique was used in the analysis of qualitative data. The purpose of descriptive analysis is to present the data collected as a result of interviews or observations to the reader in an organized and interpreted way (Marshall, 1996). The data obtained from the teacher interview form were categorized by frequency and percentage calculations and presented in tables.

Results

Findings from the Robotics Attitude Scale

Table 3 shows the sub-dimensions of the robotics attitude scale and the weighted averages and standard deviations of the students participating in the research for the overall scale.

Table 3. *Robotics attitude scale*

	M	SS
Desire to learn	3.87	0.679
Confidence	3.91	0.651
Computational thinking	3.65	0.610
Teamwork	3.80	0.688
Robotics attitude scale	3.81	0.654

In Table 3, sub-dimensions of the robotic attitude scale and information regarding the overall scale are presented. Weighted averages and standard deviations were calculated. Willingness to learn sub-dimension (M=3.87, SD=0.679), self-confidence sub-dimension (M=3.91, SD=0.651), computational

thinking sub-dimension (M=3.65, SD=0.610), teamwork the weighted average and standard deviations of the sub-dimension (M=3.80, SD=0.688) were calculated. For the overall robotic attitude scale (M=3.81, SD=0.654), weighted means and standard deviations were determined. These findings reveal that students have high attitudes in the sub-dimensions of the robotics attitude scale and the overall scale.

In Table 4, the t-test results of the students participating in the research according to gender variable are given within the scope of the robotic attitude scale.

Table 4. *T-test results of independent variables according to gender variable*

Gender	N	M	SD	F	p
Female	211	3.51	0.815	14.533	.000
Male	258	4.05	0.644		

Table 4 shows the robotic attitudes of the students participating in the research according to gender variable. T-test results of independent variables were evaluated. As a result of the independent variables T-test, it was determined that the students' robotic attitudes showed a significant difference according to the gender variable ($F = 14.533$, $p < 0.5$). The significant difference was found to be in favor of male students.

In Table 5, one-way analysis of variance (ANOVA) results is given within the scope of the robotic attitude scale, according to the class variable of the students participating in the research.

Table 5. *One-way analysis of variance (ANOVA) results according to the class variable*

Class	N	M	SD	F	P
9th grade	138	3.78	0.649	4,503	.205
10th grade	142	3.75	0.625		
11th grade	189	3.86	0.685		

In Table 5, one-way analysis of variance (ANOVA) results of the robotic attitudes of the students participating in the research were evaluated according to the variable of the class they were studying in. As a result of a one-way analysis of variance (ANOVA), it was determined that the robotic attitudes of the students did not show a significant difference according to the variable of the class they were studying in ($F = 4.503$, $p > 0.5$).

Findings from the teacher interview form

In Table 6, the questions of the teachers who participated in the research were asked: " What are your opinions about the use of robotic applications in education in Kazakh secondary schools?" Their answers to the question were evaluated.

Table 6. *Views on the use of robotic applications in education in Kazakh secondary schools*

Category	F	%
Positive	18	72
Indecisive	4	16
Negative	3	12
Total	25	100

In Table 6, the questions of the teachers who participated in the research were asked: " What are your opinions about the use of robotic applications in education in Kazakh secondary schools?" Their answers to the question were categorized. 72% of the teachers who participated in the study stated that they had a positive attitude toward the effectiveness of using mobile applications to teach robotics to students. While 16% of the teachers stated that they were undecided, 12% stated that they had a negative attitude.

Table 7 shows the questions of the teachers who participated in the research: " What are your opinions about the advantages of using robotic applications in education?" Their answers to the question were evaluated.

Table 7. *Opinions about the advantages of using robotic applications in education*

Teacher Opinions	F	%
Supports the use of technology in education	18	72
Improves students' learning skills	13	52
Improves the learning process	11	44
Provides permanence in learning	7	28
Increases interest in robotic applications	5	20
Increases students' motivation	2	8

Table 7 shows the questions of the teachers who participated in the research: " What are your opinions about the advantages of using robotic applications in education?" Their answers to the question were categorized. 72% of teachers support the use of technology in education, 52% say it improves students' learning skills, and 44% say it improves the learning process. 28% of the teachers answered that it provides permanence in learning, 20% said it increases interest in robotic applications, and 8% said it increases students' motivation.

Table 8 shows the questions of the teachers who participated in the research: "What are your opinions about the disadvantages of using robotic applications in education?" Their answers to the question were evaluated.

Table 8. *Views on the disadvantages of using robotic applications in education*

Teacher Opinions	F	%
There is a shortage of experienced teachers	16	64
It is a costly application	10	40
Causes overexposure to technology	6	24
In-service training programs for teachers are insufficient	4	16
Preparing for an event takes a lot of time	1	4

In Table 8, the questions of the teachers who participated in the research were asked, "What are your opinions about the disadvantages of using robotic applications in education?" Their answers to the question were categorized. 64% of the teachers responded that there is a lack of experienced teachers, 40% responded that it is a costly practice, and 24% responded that it causes too much exposure to technology. Additionally, 16% of teachers responded that in-service training programs for teachers are inadequate and 4% responded that preparing activities takes too much time.

In Table 9, the teachers who participated in the research asked "What are your suggestions for increasing the use of robotic applications in education?" Their answers to the question were evaluated.

Table 9. *Suggestions for increasing the use of robotic applications in education*

Teacher Opinions	F	%
A curriculum should be created in teacher training programs regarding robotic applications	20	80
Teachers should be given in-service training on robotic applications	19	76
Robotics application opportunities in schools should be increased	8	32
Students should be informed about the effectiveness of robotic applications	7	28
Seminars on robotic applications should be organized for teachers and students in schools	4	16

In Table 9, the teachers who participated in the research asked "What are your suggestions for increasing the use of robotic applications in education?" Their answers to the question were categorized. 80% of the teachers stated that a curriculum should be created in teacher training programs regarding robotic applications. 76% of the teachers responded that teachers should be given in-service training regarding robotic applications. 32% of the teachers stated that robotic application opportunities in schools should be increased, 28% stated that students should be informed about the effectiveness of robotic applications, and 16% stated that seminars on robotic applications should be organized for teachers and students in schools.

Discussions

It was determined that the students participating in the research had highly positive attitudes in the sub-dimensions of the robotics attitude scale and the overall scale. Graffin et al. (2022) also examined the effect of the robotics competition organized in their research on students' attitudes toward science courses. The findings obtained from the research reveal that students' robotic attitudes are high and that their high robotic attitudes also positively affect their attitudes toward science courses. Muniandy et al. (2022) similarly stated in their research that the robotics program had a positive and significant effect on students' attitudes toward science.

It was determined that students' robotic attitudes showed a significant difference according to the gender variable. The significant difference was in favor of male students, and it was observed that the robotic attitudes of male students were higher than female students. In their study, Van Wassenaer et al. (2023) revealed that there were differences between male and female students in the context of robotics education. It was stated in the research that this difference was in favor of male students.

The students participating in the research did not show a significant difference according to the class variable in which they studied. Findings reveal that students exhibit similar robotic attitudes. Gezgin et al. (2022) similarly revealed in their research that secondary school students' attitudes towards robotics and coding education were generally positive.

The majority of teachers participating in the research stated that they had positive attitudes toward the use of robotic applications in education in Kazakh secondary schools. Gezgin et al. (2022) stated in his research that teachers' attitudes towards educational robotics were positive, which is consistent with the findings of this research.

Teachers participating in the research were asked about their opinions on the advantages of using robotic applications in education. Teachers listed these advantages as supporting the use of technology in education, improving students' learning skills, improving the learning process, ensuring permanence in learning, increasing interest in robotic applications, and increasing students' motivation. Tzagaraki et al. (2022) evaluated teachers' attitudes towards robotic applications in education in their research. Research findings revealed that teachers are of the opinion that robotic applications improve the learning process, improve students' skills, and increase participation in robotic activities.

Teachers were asked about their opinions on the disadvantages of using robotic applications in education. Teachers listed these disadvantages as a lack of experienced teachers, high cost of implementation, excessive exposure to technology, the inadequacy of in-service training programs for teachers, and the fact that preparing activities takes a lot of time. According to Negrini (2020), some of the factors limiting robotic applications are costs, the time required to prepare the activities, and the fact that technologies are extensively present in our daily lives therefore some teachers do not want to bring them to school.

Teachers participating in the research were asked for their suggestions on increasing the use of robotic applications in education. The majority of teachers stated that a curriculum should be created in teacher training programs regarding robotic applications and in-service training should be provided to teachers regarding robotic applications. In addition, teachers suggested that schools should increase robotic application opportunities, inform students about the effectiveness of robotic applications, and organize seminars on robotic applications for teachers and students in schools. In their study, zagaraki et al. (2022) emphasized the difficulties of teachers learning and applying robotic applications and revealed the necessity of education in this field.

Conclusions

In the age of technology, we live in, an approach to education independent of technology is almost unthinkable. As technology develops in every aspect of life, it opens the door to innovations in education. The integration of robots, one of the developing technologies in recent years, into education has created a new understanding of education. Therefore, this study aimed to measure the attitudes of students in Kazakh secondary schools towards robotic applications in terms of various variables and to evaluate teachers' opinions. As a result of the research, it was determined that students' attitudes towards robotic applications in education were high. It is an expected result that male students have higher robotic at-

titudes than female students. In information technologies, male students always have higher attitudes or perceptions than female students. However, it is also an expected result that there are no differences in students' attitudes according to the classes they study. Because, attitudes towards information technologies are formed at a young age. While children play games in electronic environments, their information attitudes are also formed. The majority of teachers participating in the research have positive attitudes towards the use of robotic applications in education in Kazakh secondary schools.

There are advantages of robotic applications in education by teachers; It is expressed as supporting the use of technology in education, improving students' learning skills, improving the learning process, ensuring permanence in learning, increasing interest in robotic applications, and increasing students' motivation. The disadvantages expressed by teachers are; lack of experienced teachers, high cost of implementation, excessive exposure to technology, inadequacy of in-service training programs for teachers, and the fact that preparing activities takes a lot of time. Teachers' suggestions for increasing the use of robotic applications in education are; Creating curricula in teacher training programs on robotic applications, providing in-service training to teachers on robotic applications, increasing robotic application opportunities in schools, informing students about the effectiveness of robotic applications, and organizing seminars on robotic applications for teachers and students in schools.

Recommendations

The following suggestions were developed in line with the findings obtained from the research and teachers' opinions;

1. Although there is a need for practices to increase the robotic attitudes of all students, activities should be organized within the school to improve the robotic attitudes of especially female students.
2. The content regarding robotic applications in teacher training programs should be expanded, and teachers should be given in-service training on robotic applications.
3. Robotic application opportunities in schools should be increased and students and teachers should be informed.
4. Inclusive training seminars for teachers and students regarding robotic applications should be organized in schools.
5. This research can be repeated on a larger scale. It can be done more comprehensively, especially by including the subject of STEM. Similarly, it is recommended that experimental studies be conducted on this subject.

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Author Contributions

Project Management, R.M.I; Conceptualization, E.U; methodology, Z.Y.; software, N.K.; formal analysis, N.K.; writing—original draft preparation, K.M. and R.M.I; writing—review and editing, R.M.I and E.U. All authors have read and agreed to the published version of the manuscript.

Conflict of interests

The authors declare no conflict of interest.

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Exploring the Correlation Between Emotional Competence and the Leisure Time of Young People

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Abstract: Leisure time plays an essential role in shaping the lifestyle of young people and is closely linked to their emotional well-being and overall happiness. This paper investigates the leisure time patterns of young people and explores the correlation between these patterns and their level of emotional competence. The research involved 150 young people from South and Eastern Serbia, aged 18 to 30. Participants' emotional competence was measured using a short version of the Emotional Skills and Competence Questionnaire (ESCQ). The key determinants of emotional competence include the ability to perceive and understand emotions, express and label emotions, and manage and regulate emotions. To measure dominant leisure time patterns, we employed a specially constructed Likert-type scale, focusing on elite, hedonistic, sports–recreational patterns, and a traditional-unconventional pattern divided into passive and family categories. The results indicated that young people exhibited partial emotional competence, with the ability to perceive and understand emotions as the most developed aspect. The most frequently reported leisure activities fell under the hedonistic and passive patterns. The data revealed significant correlations between all aspects of emotional competence and the elite, hedonistic, and sports–recreational patterns, with the strongest correlation observed between emotional competence and the elite pattern, which includes cultural activities, reading, and volunteer work. The results indicate that a higher level of emotional competence development is associated with the selection of quality leisure activities. Therefore, we could rely on the educational potential of leisure time to promote the development of emotional competence and vice versa.

Keywords: *leisure time, emotional competence, emotional education, young people.*

Introduction

Leisure time affects all areas of social life, but its meaning varies among different groups. It is highly appreciated by hardworking individuals or students who have numerous obligations. However, it can be neglected by the unemployed, as it dominates the entire framework of their everyday life. It could be structured and focused on enjoyment or personal development, or unstructured and marked by boredom. In any case, it is an important part of everyone's life.

For young people, according to many authors (Ilišin, 2007; Mlinarević, 2004; Zeijl et al., 2001), leisure time is even more important, as it can support the intensive formative development they are undergoing. It ensures young people the freedom to explore their interests and find fulfillment, helping them achieve self-actualization. Furthermore, wisely chosen leisure activities offer rest, recreation, and personal growth, which are essential during this stage of life. Some data indicate that young people are often engaged in unstructured and unproductive activities, such as spending time with friends, participating in hedonistic activities like entertainment and music (Mlinarević, 2004), using the internet (Opić et al., 2014), or engaging in unstructured sports activities (Petrović et al., 2018). This fact makes educational interventions in this realm a necessity. Education should establish a balance between responsibility and

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freedom. For example, with age, the frequency of unstructured physical activities declines during the transition from adolescence to adulthood; however, the frequency of physical activities in adolescence still predicts physical activity levels in adulthood, especially among males (Kjønniksen et al., 2008). So, educators need to empower young people to make more informed choices and stick to them. Developing a culture of responsible leisure time use, focusing on organized and productive activities, and finding a balance between passive and active pursuits contribute to personal development and can be beneficial for physical, cognitive, and emotional well-being.

As it involves the free choice of activities and personal contacts, leisure time represents an open space for young people to explore their feelings and emotions. They are less likely to suppress emotions and exhibit self-doubt and insecurities during activities they freely choose for themselves. Moreover, they will develop the ability to perceive and understand their own emotions, express and label them, and manage and regulate them, which are the primary assets of emotional competence (Salovey and Mayer, 1990). In this sense, leisure time can be the basis for emotional development, and its potential should be taken into consideration by educators.

Considering that the emotional aspect of personality influences the choices we make, including the choice of leisure activities, we argue that there is a two-way connection between the emotional competence of young people and the way they spend leisure time. We expect young people with highly developed emotional competence to be more likely to participate in organized, social, and humanitarian activities, and those that support their personal development.

We assumed that people who are more inclined to dedicate their time to helping others through various forms of volunteering and social activism have a higher level of emotional competencies. Young people whose free time is filled with various social activities have more opportunities to develop socio-emotional competencies, unlike those who spend their free time passively. To test this assumption, we dedicate this paper to investigating the correlation between emotional competence and leisure time among young people.

Theoretical Framework

Free choice in leisure time enhances enjoyment, promotes positive personality development, and is closely linked to emotional well-being and overall happiness. The selection of leisure activities greatly influences one's lifestyle, and it develops in patterns that can be recognized and studied.

Patterns in leisure-time activities are determined by the frequency of a particular group of activities and explain people's interests and life orientations. The most frequently researched patterns across different cultures are cultural patterns (Ilišin, 2007) and family patterns (Zabriskie et al., 2001). Initially, cultural patterns were divided into rural, urban, and elite patterns; but, five additional patterns were later added, including the sport pattern, family pattern, passive pattern, media pattern, and activist pattern (Ilišin, 2007). The family pattern can also be divided into two: a core pattern that includes family lunch, watching TV, and backyard activities, and a balanced pattern encompassing activities such as community events, tourism, and adventure activities (Zabriskie et al., 2001).

For this research, we employ a division of leisure patterns into elite, hedonistic, sports-recreational, and traditional-unconventional pattern, as described by Mlinarević (2004). The traditional-unconventional pattern is based on family activities, traditional folklore games, as well as unstructured activities, including watching TV, using the Internet, and playing computer games. We divided this pattern into the family pattern and the passive pattern for the sake of better clarity. The sports-recreational pattern encompasses a range of active and recreational sports activities, attending sporting events, and social games. The hedonistic pattern represents leisure activities that provide fun and enjoyment, such as attending clubs and social gatherings.

The starting point for our research is the previously assumed correlation between different emotions, leisure activities, and general well-being and mental health. Leisure time provides numerous opportunities for practicing skills such as tolerance, democratic behaviour, conflict resolution, and communication skills (Opić et al., 2014), which highlight its significant potential for social and emotional development and increase our research interest in this topic. Engagement in leisure activities is positively associated with the expression of positive emotions, especially in females (Zhang and Zheng, 2017). Pleasant feelings associated with leisure activities are often linked to better mental health; however, a high frequency of entertainment activities can also harm mental health (Mana and Barman, 2020). Leisure activities based on competition, such as

sports or games, can undermine interpersonal communication and support in close relationships. However, participation in shared activities with peers is indirectly correlated with the development of interpersonal competence (Tuggle, 2014). Also, previous research confirmed the connection of positive emotions with cultural leisure activities: positive emotions such as joy and curiosity develop before and increase during the leisure travel experiences (Mitas et al., 2012); high school theatre experience correlates with emotional knowledge and developing the strategies to regulate emotions (Larson and Brown, 2007).

Emotional competence is a learned ability that is manifested in external activity or work and is based on emotional intelligence (Goleman, 2001). The concept of competencies as learned abilities forms the basis of Goleman's idea of emotional intelligence. According to the construct of emotional intelligence by Mayer and Salovey, there are four levels of ability, ranging from basic psychological processes to more complex ones that integrate emotions and cognition, namely: perception and expression of emotions; the emotional aspect of thinking, understanding, and analysing emotional information; and emotion regulation. Within each of these key competencies, there are individual competencies, such as the ability to identify emotions, the ability to use emotional states to solve problems, and the ability to understand the relationships between different emotions (Salovey et al., 2008; Salovey and Mayer, 1990). In this research, we focused on the main aspects of emotional competence, which are the abilities to perceive and understand emotions, express and label emotions, and manage and regulate emotions.

Although emotional competence and leisure time are widely investigated phenomena, only a few studies indicate mutual relationships between them. One of the first studies examining the influence of competencies on leisure activities dates back to the past century and confirms that emotional competence determines the frequency of activities, as well as the fact that the lower the emotional competence, the higher the subjective feeling of difficulty in everyday activities (Pushkar et al., 1997). Nowadays, strong positive correlations between emotional intelligence and physical leisure activities have been confirmed, particularly in aspects of emotional competence, such as self-awareness, emotional stability, and relationship management. However, correlations were not significant regarding empathy and altruistic behaviour (Singh and Fellow, 2017).

The role of leisure in developing and utilizing socioemotional competence is highlighted in a review paper by Iwasaki (2006). The author distinguished four aspects of the connection between them: leisure increases positive emotions and well-being; positive identities and self-esteem can be gained through leisure; leisure activities develop social and cultural connections and skills; and leisure contributes to personal and learning development.

Materials and Methods

This paper aims to identify the dominant leisure patterns of young people in Serbia and to investigate whether their emotional competencies correlate with the dominant patterns of their leisure time. Our primary hypothesis was that young people with more developed emotional competence would be more productive in their free time and would more often choose activities that have a positive influence on their development and lifestyle. Thus, emotional competence will positively correlate with elite, sport-recreational, and family patterns.

Data collecting and processing

The theoretical foundation for developing the first instrument was based on the leisure patterns system established by Mlinarević (2004), which we adapted by splitting the traditional-unconventional pattern into two categories: the passive leisure pattern and the family pattern. To identify the dominant leisure patterns among participants, we used a 5-point Likert scale specially designed for this study. Participants rated how often they engaged in activities listed on the scale. It included 43 items (activities), divided into five subscales: elite, hedonistic, passive, sports–recreational, and family pattern. The elite pattern subscale examined the social and personal engagement of young people in their leisure time. This subscale consisted of eleven items, including: I use my free time to read books; I attend seminars and lectures in areas that interest me; I participate in the activities of a youth association; I participate in humanitarian activities; and I visit cultural and artistic events organized in my city. The hedonistic pattern encompasses various forms of unstructured entertainment, leisure activities such as listening to music, and modern forms of communication. The following items represent it: I visit festivals and concerts; I play board games

(such as cards and Monopoly); I spend my free time during the day drinking coffee with friends; I relax to good music and have a good time with friends. The passive pattern includes activities such as resting, lounging, watching television, playing games on electronic devices, and using the Internet and social networks. Nine items cover the passive pattern, including: I watch reality shows; I use my leisure time to watch movies and series; I play games on my phone; I scroll social networks; I use my leisure time to get a good night's sleep. The subscale related to the sports-recreational pattern contains eight items and explores participation in active and recreational sports, attendance at sporting events, and involvement in sports in both active and passive forms. The representative items for this subscale are: I spend time with my family or friends engaging in joint hobbies or recreational activities (such as cycling, going to the pool, or participating in sports); I practice aerobics, fitness, or visit the gym; I follow sports channels; and I attend sports events and competitions. The family pattern emphasizes the importance of fostering family and traditional values during leisure time, encompassing activities such as caring for the home and family, as well as respecting traditions, customs, and religious beliefs. It contains nine items, including the following: I organize or attend family gatherings; I respect the family custom of having lunch or dinner together; I perform household chores such as vacuuming, dusting, and cleaning the house; I participate in caring for a pet. The alpha coefficient value of the scale was α = 0,870, indicating high reliability.

A shortened version of the ESCQ (Takšić, 2002) scale, comprising 15 items, was used to measure the emotional competencies of participants. In our sample, the alpha coefficient value was 0,824. Initially, it was developed in a Croatian setting as a 45-item scale based on the theoretical framework of the emotional intelligence model (Mayer and Salovey, 1997) and validated in different countries (Avsec et al., 2020; Faria et al., 2006). The ESCQ also showed strong positive correlations with the maintenance of positive mood and subjective well-being (Takšić, 2002). It seems reasonable to expect that abilities related to perception, understanding, managing, and using emotions to achieve desired goals would correlate with dominant leisure patterns.

The research was conducted among young people aged 18 to 30 from the southern and eastern regions of the Republic of Serbia. Data collection was conducted online using a Google Form questionnaire. We used convenience sampling based on voluntary participation and the principle of anonymity. After collecting the data, the sample was divided into subgroups based on gender (male, 46.7%, and female, 53.3%), age (18-20, 18%, 21-25, 54%, and 26-30, 28%), and work engagement (student, 42,7%, unemployed, 23,3%, and employed,34%).

Statistical Package for the Social Sciences (SPSS) version 20. was used for processing data. To ensure the reliability of the instruments, Cronbach's alpha test was applied. To determine the frequency of leisure patterns and the level of emotional competence, we calculated descriptive statistics. For analyzing the differences between subgroups, we conducted a t-test and an ANOVA test. Finally, to investigate the correlation between emotional competence and dominant leisure patterns, we calculated Pearson's coefficient of correlation.

Results

The results are presented in three parts. First, we will describe the emotional competence of our participants, then the dominant pattern of leisure time, and finally, the established correlation between them, which will explain the nature of the connection between emotional competence and leisure activities.

Emotional competence of young people

As we mentioned earlier, emotional competence can be defined as the ability to perceive and differentiate your own emotions and the emotions of others, as well as using emotional knowledge to develop social interactions and regulate behavior (Peter Salovey and Mayer, 1990). In this research, based on self-reports from participants, we measured the level of three aspects of emotional competence: the ability to perceive and understand emotions, express and label emotions, and manage and regulate emotions.

Table 1. Level of emotional competence

	N	M	Sd
Ability to perceive and understand emotions	150	**4.06**	0.16
Ability to express and label emotions	150	3.91	0.63
Ability to manage and regulate emotions	150	3.73	0.96

The statistical data, presented in Table 1, suggest that our respondents are partially emotionally competent. To investigate the differences in levels of development of aspects of emotional competence, we ranked them by calculating the arithmetic means for each aspect. Results indicate that the ability to perceive and understand emotions (M = 4.06) was the most developed aspect of their emotional competence, and the ability to manage and regulate emotions (M = 3.73) was the least developed. However, there were minimal differences among means. These results suggest that our respondents utilize their emotional knowledge to regulate emotions and behavior, a characteristic of emotionally competent individuals.

Regarding the gender of the respondents, no statistically significant difference was found, indicating that the emotional competence of young people does not differ by gender in any of the components of emotional competence studied.

Regarding the age of our participants, a statistically significant difference was observed in their abilities to perceive and understand emotions (ANOVA test = 7.670; $p = 0.01$; $p < 0.05$) and their abilities to express and label emotions (ANOVA test = 3.330; $p = 0.39$; $p < 0.05$). Both aspects of emotional competence are more developed in the older group of participants (26-30 years), which is expected based on existing literature data that emotional competence develops with age.

Patterns of leisure time of young people

All the activities that young people engage in during their leisure time can be observed through patterns. For this research, we investigated the frequency of five leisure patterns among young people and analyzed the differences in these patterns by gender, age, and employment status.

Table 2. Dominant leisure time patterns

	N	M	Sd
Hedonistic pattern	150	3.83	0.63
Passive pattern	150	3.48	0.56
Family pattern	150	3.33	0.85
Sports-recreational pattern	150	3.04	0.77
Elite pattern	150	2.69	0.81

Results indicate that the most frequent activities generally belong to the hedonistic and passive pattern, while the least dominant are leisure activities associated with the elite pattern. These results are not surprising, considering that the hedonistic pattern includes activities such as going out and having fun in clubs, while the passive pattern includes playing video games and watching television. These activities are characteristic of the young population's leisure time. Although they are shown to have a low frequency, the activities of the elite pattern are not negligible, especially considering that these are academic and cultural activities that, by their nature, do not usually involve daily implementation. Nevertheless, these numbers provide us with important information that suggests encouragement toward more productive leisure is desirable.

Considering the gender of the participants, a significant difference was confirmed in the elite and family pattern of leisure time. The elite pattern is significantly more dominant (t-test = -5.680; $p = 0.00$; $p < 0.05$) in females than in males, as well as the family pattern (t-test = -10.069; $p = 0.00$; $p < 0.05$). This data aligns with the cultural perspective of our society, in which women tend to pay more attention to culture, art, and volunteer work compared to men, as well as with the traditional division of roles in patriarchal culture, which is characteristic of our society, where women are often more dedicated to family responsibilities.

Observing the age, statistically significant differences in the representation of elite, family, and passive leisure patterns are confirmed. The elite (ANOVA test = 9.71; $p = 0.00$; $p < 0.05$) and family pattern (ANOVA test = 22.06; $p = 0.00$; $p < 0.05$) are most common among young people from the oldest group of

respondents (26-30 years). When it comes to the passive pattern (ANOVA test = 15.08; p = 0.00; p < 0.05), the data show that the passive pattern is most common in the youngest group of respondents (18-20 years). These results are also expected, assuming that the pattern implying easy fun, such as playing games, watching movies, and TV channels, would be the choice of senior high schoolers and first-year college students.

Table 3. Dominant leisure pattern regarding participants' employment

	Employment	N	M	Sd	Anova	df	P
Elite pattern	Student	64	2.85	0.75	5.78	2	0.004
	Employed	51	2.75	0.77			
	Unemployed	35	2.12	0.85			
Hedonistic pattern	Student	64	3.94	0.61	3.21	2	0.043
	Employed	51	3.64	0.64			
	Unemployed	35	3.83	0.48			
Sports – recreational pattern	Student	64	3.17	0.83	4.24	2	0.016
	employed	51	2.79	0.74			
	unemployed	35	3.17	0.58			
Family pattern	Student	64	3.51	0.79	12.36	2	0.000
	employed	51	3.51	0.71			
	unemployed	35	2.74	0.89			
Passive pattern	Student	64	3.51	0.44	15.12	2	0.000
	employed	51	3.20	0.57			
	unemployed	35	3.82	0.54			

Statistical analyses of the data, which included employment as a research variable (Table 3), revealed a statistically significant difference in all investigated leisure patterns. Elite and hedonistic leisure patterns are significantly represented in the subgroup of employed students, in contrast to other groups. The family leisure pattern is dominant in the subgroups of students and employed participants, but it is significantly lower in the subgroup of unemployed participants.

The passive pattern is most prevalent among unemployed respondents, followed by students, and is least prevalent among the employed. These results are supported by the data referred to earlier, which show that the highest prevalence of passive pattern is among the youngest population, between 18 and 20 years of age, most of whom are unemployed.

Correlation between leisure time patterns and emotional competence

After determining the dominant leisure pattern and level of emotional competence among our respondents, this part of the research investigated the relationship between young people's emotions and their leisure time spending.

Table 4. Correlation between leisure time patterns and emotional competence

		Ability to perceive and understand emotions	Ability to express and label emotions	Ability to manage and regulate emotions
Elite pattern	Pearson's correlation	0.492**	0.532**	0.310**
	P	0.000	0.000	0.000
Hedonistic pattern	Pearson's correlation	0.242**	0.348**	0.180*
	P	0.003	0.000	0.027
Sports-recreational pattern	Pearson's correlation	0.209*	0.189*	0.227**
	P	0.010	0.021	0.005
Family pattern	Pearson's correlation	0.388**	0.417**	0.160
	P	0.000	0.000	0.051
Passive pattern	Pearson's correlation	-0.073	0.069	0.033
	P	0.373	0.401	0.691

The obtained data showed a moderate to strong positive correlation between all aspects of emotional competence and elite, hedonistic, and sports–recreational patterns. The most significant correlation was between all aspects of emotional competence and the elite pattern (which includes cultural activities, reading, and volunteer work) of spending leisure time. The family pattern in leisure time is also positively correlated with the ability to perceive and understand emotions, as well as to express and label them.

Results did not indicate any significant correlation between the passive pattern of spending leisure time and any aspect of emotional competence. This means that our participants choose activities from the passive pattern regardless of their level of emotional competence development.

Discussion

Based on the results, we can conclude that our participants spend most of their leisure time in hedonistic and passive activities. This is in accordance with data from previous studies (Opić et al., 2014; Petrović et al., 2018) as well as the characteristics of the participants' age. Since the nature of elite activities usually does not involve daily engagement, we conclude that young people in our sample spend a satisfying, though improvable, amount of productive leisure time. Elite leisure pattern activities have unquestionable benefits (Fletcher et al., 2003; Larson and Brown, 2007; Mitas et al., 2012) and contribute to overall well-being, education, and emotional development, making them important assets to further development. Data on gender and age differences provide us with more information and guidance on how to enhance this practice. Our results, similar to some previous research (Ilišin, 2007; Zeijl et al., 2001), show that activities included in the elite leisure pattern are more dominant among older participants and females, indicating which parts of the population the action should be directed toward.

Regarding emotional competence, our participants demonstrated a highly developed ability to perceive and understand emotions, as well as slightly less developed abilities to express and label emotions; however, their ability to manage and regulate emotions was partially developed. These results are important for understanding the emotional development of young people because emotional awareness and understanding of emotions are the first steps toward emotional regulation (Ikävalko et al., 2020). Still, there is more work to be done on the way toward achieving full emotional maturity and emotionally competent behavior.

Interestingly, contrary to our expectations, gender was not a significant variable, as results showed similar emotional competence in both female and male participants. On the other hand, expectations regarding age were confirmed, with results indicating that older participants (aged 26-30) are significantly more emotionally competent. Similar results were obtained by Dimitriu and associates (Dimitriu et al., 2014) in a sample consisting of university students.

Ultimately, the primary objective of this research was to investigate whether the type of leisure activities, as represented by leisure patterns, correlates with the level of emotional competence among young people. Results indicate a significant correlation with elite, hedonistic, and sport-recreational patterns, but no significant correlation with the passive leisure pattern. The most significant correlation was found between all aspects of emotional competence and the elite pattern of spending leisure time, which includes cultural activities, reading, and volunteer work. This confirmed our hypotheses, based on previous studies, which showed that activities such as writing, composing music, painting, and other cultural pursuits significantly enhance emotional creativity (Trnka et al., 2016). Additionally, research has found that theater experiences enhance the ability to regulate emotions (Larson and Brown, 2007).

Although the previous research (Mahoney and Stattin, 2000) confirms a connection between unstructured leisure activities and antisocial behavior, different approach to those activities implies that unstructured activities based on fun (in our research included into hedonistic pattern) are important for young people because represent time with low stress, and enhance enjoyment (Harshita Singh, 2020). On the other hand, participating in active sports helps regulate emotions. It has been confirmed that, with an increasing degree of mental readiness, athletes also enhance their ability to regulate emotions (Yalcin et al., 2021). Sports activities can serve as an educational tool to integrate people, enhance children's success, and promote an active lifestyle and overall well-being (Stănescu et al., 2020). Regarding our results, we can conclude that the primary characteristics of sport, including activity, peer interaction, and free choice, are associated with recreational sport and contribute to emotional development.

Observing only the frequency of activities, involvement in more leisure activities was confirmed to be connected to more positive emotions (Zhang and Zheng, 2017). The referred research did not differ-

entiate between the types of leisure activities; however, those results can still explain the high correlation we noted with emotional competence and the three different leisure patterns. Other research indicates that the high frequency of entertainment activities (more than 6 hours) negatively correlates with mental health (Mana and Barman, 2020), which can explain our results showing no correlation between passive leisure activities and emotional competence. Based on an analysis of numerous theoretical and research papers, Mansfield and associates (Mansfield et al., 2020) concluded that promoting well-being is possible by modifying leisure time and focusing on structured, cultural, and high-quality activities. This is especially important to consider, given that young people often engage in various activities that change frequently (Zeijl et al., 2001).

Some researchers have confirmed that young people use leisure activities to manage stressors in everyday life, and based on this data, have recommended developing social-emotional competence programs that help reduce stress, primarily through sports activities (Hutchinson et al., 2008). In this regard, a connection has been confirmed between semiprofessional and hedonistic sports activities and positive emotions, as well as tension reduction (Kerr et al., 2002). Additionally, a higher level of emotional and social competence has been confirmed to predict future engagement in leisure activities (Pushkar et al., 1997). All noted correlations in our research, as well as discussed data, indicate that emotionally competent young people choose leisure activities that further contribute to their emotional development.

Conclusions

The first insight this research provides is regarding the emotional competence of young people in Serbia. The general conclusion that emotional competence is only partially developed in our population suggests that, although we have a solid foundation, there is still a need for educational efforts to focus on enhancing emotional competence. In this context, special attention should be directed toward developing the ability to manage and regulate emotions, which represents a higher level of emotional competence and is the least developed. Furthermore, the results indicate that the primary intervention should target the younger population, regardless of gender.

The second conclusion drawn from our findings is that young people in Serbia should be offered and encouraged to engage in more productive leisure activities. A pattern of passive leisure activities predominates across the entire population, particularly among younger, male, and unemployed participants. While this pattern is not inherently harmful, it should not overshadow other leisure activities that promote physical and mental well-being.

Lastly, the results demonstrated a significant correlation between emotional competence and leisure patterns. Until further research clarifies the nature of this mutual influence, we believe that this connection is bidirectional. More emotionally competent participants tend to choose more productive activities that have a positive impact on their own lives and those of others. Additionally, fulfilling leisure time also enhances emotional competence. One effective strategy for improving both areas of research is to integrate emotional education with thoughtfully organized leisure activities.

Ultimately, the study's findings have significant implications for future research directions. The connection between leisure time and emotional education is a valuable research field and could help us better understand both phenomena. As the foundation for leisure culture and emotional competence is formed during the adolescent period, it deserves special attention from researchers, which our results also confirm. Further studies could also consider other factors that were not included in this study, such as the participants' economic status and available community resources. Finally, future studies should address the methodological and interpretive limitations of this study. Refining sampling methods, such as adopting random sampling to improve representativeness, and incorporating comprehensive analyses, such as factor analysis, would also enhance the understanding of how leisure time is connected to emotional competence. These steps would facilitate more accurate findings, the development of effective interventions and educational policies.

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Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, J.P., D.D.P., and K.R.; methodology, J.P. and K.R.; formal analysis, D.D.P., and K.R.; writing—original draft preparation, J.P. and D.D.P.; writing—review and editing, J.P. and D.D.P.
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Spectral Power of Background EEG, Complex Visual-Motor Response, Galvanic Skin Response and Electrocardiogram Parameters in Adolescents With Autism Spectrum Disorders and Mental Retardation

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Abstract: The paper presents the results of a study of the parameters of the galvanic skin response, electrocardiogram, complex visual-motor response parameters and spectral power of the background EEG on a sample of 34 schoolchildren aged 12 to 17 years with autism spectrum disorders and mental retardation. Electroencephalogram and polygraphic channels (electromyogram, galvanic skin response, electrocardiogram) were recorded. Intelligence was diagnosed using the WISC test by D. Wechsler. The functional state was assessed by complex visual-motor response parameters using the Psychophysiologist device. The study found that a higher spectral power of the background EEG in the alpha range in the parietal region corresponds to a higher level of general intelligence in adolescents with autism spectrum disorders and mental retardation. Evaluation of the complex visual-motor reaction showed that a higher spectral power of the background EEG in the beta-1 range of the right and central occipital region corresponds to the average class of sensorimotor reactions. A higher spectral power of the background EEG in the beta-2 range of the right frontal region is noted in adolescents with a higher class of sensorimotor reactions. The obtained results are used in the development of individual correctional programs for adolescents with autism spectrum disorders and mental retardation.

Keywords: *spectral power of background EEG, complex visual-motor reaction, adolescents with autism spectrum disorders and mental retardation.*

Introduction

There is an increase in the number of children and adolescents with autism spectrum disorders (ASD) and mental retardation worldwide. With the change in society as well as the receipt of new data on the specifics of the course of these types of disorders, it is becoming increasingly clear that the integration of individuals with these characteristics is possible based on knowledge of the psychophysiological basis of the development of children and adolescents (Vorobyeva and Kaidanovskaya, 2018). Children with ASD often have brain macrocephaly, with an increase in volume and density recorded in both white and gray matter, especially in the frontal and temporal lobes (Zhao et al., 2022) and studies of adults show data on both increased and decreased brain volume (Arutiunian et al., 2023). Structural and functional abnormalities have been found in the basal ganglia, striatum, hippocampus, and hypothalamus (Zhao et al., 2022). Brain tissue studies show active neuroinflammatory processes in the cortex and white matter (Pardo et al., 2007), changes in sulcal depth in areas of the brain that are associated with language (Arutiunian et al., 2023), reduced dendritic branching, increased density of smaller neurons in the hippocampus and amygdala nuclei, decreased number of Purkinje cells, and underdevelopment of inhibitory neurons (Pardo et al., 2007). Individuals with ASD have elevated levels of serotonin, glutamate, aspartate, phenylalanine, histidine, tyrosine, and taurine, and decreased levels of oxytocin, endorphins, glutamine, and asparagine in the blood (Brister et al., 2022; Zhao, Zhang et al., 2022).

The electrical brain activity of children with ASD has such features as the lack of expression of the main rhythm and zonal differences, increased electrical activity of the beta range in combination

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with diffuse waves of theta and delta ranges, and reduced amplitude indicators of evoked potentials, an asymmetric distribution in the occipital regions and a general decrease in alpha rhythm activity, a higher spectral power of the gamma rhythm (Zhukova, 2016; Misyuk, 2012). Researchers also note the presence of hyperexcitable areas of the brain, differences in areas of activity from the norm, changes in coherence and disruption of information exchange processes between different areas of the brain (Boutros et al., 2015; Gamirova et al., 2023). Studies also report redundancy of local connections of the cerebral cortex areas and insufficiency of functional interaction of relatively remote regions (frontal and parietal areas of the neocortex) (Pavlenko et al., 2023). The features of the disorders vary depending on the type of ASD and its manifestations. One of the EEG features of people with ASD is the suppression of the mu rhythm (a subtype of the alpha rhythm recorded during sensorimotor activation). A change in the manifestation of the mu rhythm can signal a malfunction of mirror neurons (Misyuk et al., 2012; Pavlenko et al., 2023). The frequency of epileptic seizures reaches 30% in people with ASD (Misyuk et al., 2012), with various forms of epileptiform activity noted (Boutros et al., 2015; Belousova et al., 2018).

The peripheral nervous system shows reduced phasic and tonic components of the electrodermal activity in individuals with ASD, as well as no change in amplitude when emotional stimuli are presented compared to normotypic individuals, indicating autonomic dysregulation (Farmer et al., 2017; Gul et al., 2020). Signs of increased intracranial pressure are noted (Avtenyuk, 2016). A reduced level of muscle activation is noted (Borji et al., 2014). Heart rate variability in individuals with ASD is characterized by increased background heart rate with decreased background peripheral nervous system activity and reactivity to psychosocial stimuli (Belova et al., 2017).

A lot of attention is paid to differential diagnostics in the work with children with mental retardation, in particular, an audiological examination is carried out in order to differentiate children with mental retardation from the children with hearing impairment (Karantysh et al., 2022). Characteristic features of the EEG of children with mental retardation are a decrease in the frequency of the alpha rhythm and its unevenness, suppression of the theta rhythm and gamma rhythm, high-amplitude delta rhythm (especially in the left frontal-temporal region) (Lobasyuk et al., 2021). Non-standard sources of rhythms in the brain are also noted (Lobasyuk et al., 2023). Active epileptic and paroxysmal disorders are observed (Ünal et al., 2009). Up to 20% of children with mental retardation have a right lateral profile (Lobasyuk et al., 2021).

The theoretical and methodological basis of this work were formed by the ideas that have been developed in Russian and international clinical psychology about the specifics of the development of adolescents with ASD and mental retardation (Appe, 2019; Volkmar et al., 2014; Grigorenko, 2018; Dovbnya S. et al., 2022; Isaev, 2007); standards for psychological assessment of intelligence (Clinical, 2021; Clinical, 2024); psychophysiological approach (Blinova et al., 2017; Blinova et al., 2017; Barbier et al, 2022; Borji et al, 2014); ideas about the relationship between EEG parameters and intellectual indicators (Gamirova et al., 2023; Pavlenko et al., 2023; Lobasyuk et al., 2021).

In one of our previous works, a relationship was also established between general intelligence and functional state in adolescents with ASD and mental retardation (Vorobyeva and Rahimova, 2023).

In correctional and developmental work with adolescents with autism spectrum disorders and mental retardation, the issue of taking into account their individual psychological characteristics (specificly, intellectual characteristics; neuropsychological characteristics; psychophysiological characteristics, such as the speed of response and the characteristics of the functional state, manifested in the parameters of a complex visual-motor reaction, as well as the characteristics of the spectral power of the background EEG and during activation procedures) remains insufficiently studied.

Materials and Methods

The study involved 34 teenagers (7 girls and 27 boys) aged 12–17 with ASD and mental retardation, students at the Rostov Specialized Boarding School No. 41 and the Rostov Specialized Boarding School No. 42 (Rostov-on-Don). The study was conducted individually.

Research methods. The electroencephalograph “Encephalan-EEGR-19/26” manufactured by “Medicom” in Taganrog (Russia) was used to record the EEG. 21 electrodes were placed according to the International 10–20 electrode placement system in Fp1, Fp2, Fpz, F3, F4, F7, F8, Fz, C3, C4, Cz, T3, T4, T5, T6, P3, P4, Pz, O1, O2, Oz positions using a monopolar scheme with ipsilateral earlobe referents. Polygraphic channels (electromyogram (EMG), galvanic skin response (GSR), electrocardiogram (ECG))

were used to track and suppress artifacts. Recording was made in an isolated room. The analysis epoch was 10 minutes. The resistance did not exceed 10 kOhm. The EEG recording was performed with the "background", "eyes open", "eyes closed" functional tests, tests with photo- and phono-stimulation, test with hyperventilation. This article presents estimates of the spectral power absolute values of the background EEG in the ranges of delta-1 (0-2 Hz), delta-2 (2-4 Hz), theta (4-7 Hz), alpha (8-12 Hz), beta-1 (14-20 Hz), beta-2 (20-35 Hz).

The children's version of the D. Wechsler test (WISC) was used in the adaptation of A. Yu. Panasyuk for the diagnosis of intelligence (Panasyuk, 1991).

The functional state was assessed based on the parameters of the complex visual-motor reaction (CVMR) using the UPFT-1/30 Psychophysiologist psychophysiological testing device (Medicom MTD, Russia, Taganrog). The level of sensorimotor reactions (LOSR) was assessed as follows: >0.81 — high; 0.58–0.8 — above average; 0.59–0.36 — average; 0.37–0.1 — below average; < 0.1 — low (Methodical, 2015). Statistica 10.0 was used for statistical processing (Spearman's rank correlation coefficient, one-way analysis of variance (ANOVA), post-hoc analysis with Bonferroni correction).

Results

Spectral power absolute values analysis of the background EEG (with closed eyes) was performed. Table 1 presents the results of spectral power absolute values analysis of background EEG by ranges (delta-1 (0–2 Hz), delta-2 (2–4 Hz), theta (4–7 Hz), alpha (8–12 Hz), beta-1 (14–20 Hz), beta-2 (20–35 Hz)) in Fp1, Fp2, Fpz, F3, F4, F7, F8, Fz, C3, C4, Cz, T3, T4, T5, T6, P3, P4, Pz, O1, O2, Oz leads.

Table 1. *Results of the analysis of spectral power absolute values of background EEG*

Positions	Power by range (μV^2)					
	Delta-1	Delta-2	Theta	Alpha	Beta-1	Beta-2
Fp1	9,5±5,6	15,3±7,9	18,1±14,2	21,4±18,4	6,3±4,4	0,1±0,1
Fp2	9,4±4,7	16,0±8,2	21,2±15,5	38,4±44,9	7,9±6,5	0,1±0
Fpz	15,8±7,8	20,7±8,5	19,6±10,8	16,7±11	6,2±3,3	0,1±0,1
F3	10,6±5,8	16,4±8,3	21,4±17,2	39,9±39,3	7,9±6,2	0,1±0,1
F4	10,4±5,0	16,4±8,3	23,7±21,2	63,9±87,4	8,6±5,4	0,1±0
F7	8,9±4,4	14,6±7,2	18,6±13,1	22,5±21,0	6,6±5	0,1±0
F8	9,5±5,6	15,3±7,9	18,1±14,2	21,4±18,4	6,3±4,4	0,1±0,1
Fz	13,1±5,5	20,0±7,6	26,3±14,3	25,4±20	7,9±4,6	0,1±0,1
C3	11,4±6,3	17,5±9,3	23,2±19,0	57,6±61,7	9,6±6,5	0,2±0,2
C4	11,9±5,1	18,1±8,6	26,1±18,8	37,6±35,8	8,4±6,2	0,1±0
Cz	12,1±5,0	20,3±8,5	27,6±18,4	37,4±34,8	8,6±5,9	0,1±0,1
T3	9,4±4,7	16,0±8,2	21,2±15,5	38,4±44,9	7,9±6,5	0,1±0
T4	10,6±5,8	16,4±8,3	21,4±17,2	39,9±39,3	7,9±6,2	0,1±0,1
T5	10,4±5,0	16,4±8,3	23,7±21,2	63,9±87,4	8,6±5,4	0,1±0
T6	11,4±6,3	17,5±9,3	23,2±19,0	57,6±61,7	9,6±6,5	0,2±0,2
P3	12,3±5,5	19,7±9,0	24,8±17,7	72,7±91,5	9,6±6,7	0,1±0
P4	11,7±5,1	17,9±9,6	26,5±19,3	71,3±91,0	10,1±7,5	0,1±0,1
Pz	12,4±5,7	20,1±9,6	26,6±19,1	75,8±96,9	10,2±7,6	0,1±0,1
O1	11,6±6,0	17,2±9,5	21,6±16,1	90,8±97,9	10,7±6,5	0,1±0,1
O2	10,8±5,5	14,5±7,4	22,0±17,0	66,9±56,5	11,9±6,6	0,2±0,2
Oz	11,3±6,1	18,0±10,5	22,3±18,2	75,0±78,4	10,8±6,9	0,2±0,1

The data presented in Table 1 shows that adolescents with ASD and intellectual disability have absolute spectral power values of background EEG within the normal range in the delta-1, theta and beta-1 ranges, a wide range of absolute spectral power values in the alpha range, as well as an increase of absolute spectral power values in the delta-2 range and a decrease in absolute spectral power values in the beta-2 range compared to age-related normative indicators (Tereshchenko et al., 2010). The following descriptive statistics were obtained from the participants' completion of the WISC test: verbal intelligence 63.7±17.5, non-verbal intelligence 82.5±24.8, general intelligence 69.6±20.4. Analysis of the general intelligence level showed that 16 people (52%) have the "intellectually poor" level, 4 people have the "borderline" level (13%), 5 people have the "below average" level (16%), 5 people have the "average" level (16%), 1 person has the "high" level (3%). Results show that the study participants have a statistically higher level of non-verbal intelligence compared to verbal intelligence ($z = 2.7$, $p < 0.01$).

A one-way analysis of variance was carried out for the spectral power absolute values of the background EEG of different ranges depending on the level of general intelligence. Further, in Figures 1, 2 and 3, statistically significant results of one-factor ANOVA are presented, where the assessment of the level of general intelligence was used as an independent variable, and the assessment of the spectral power of the background EEG was used as a dependent variable.

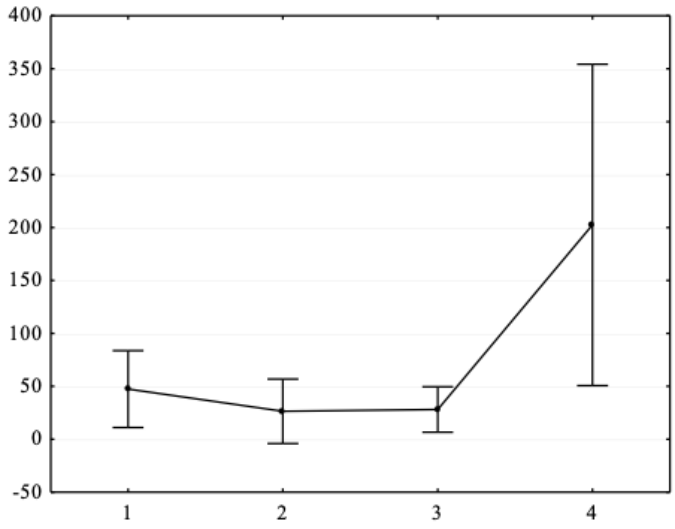

Figure 1. Results of one-way analysis of variance (X-axis – independent variable: general intelligence level (1 - intellectually poor, 2 - borderline level, 3 - below average, 4 - average level); Y-axis – dependent variable – spectral power absolute values of the background EEG alpha range in P3 lead, μV2.

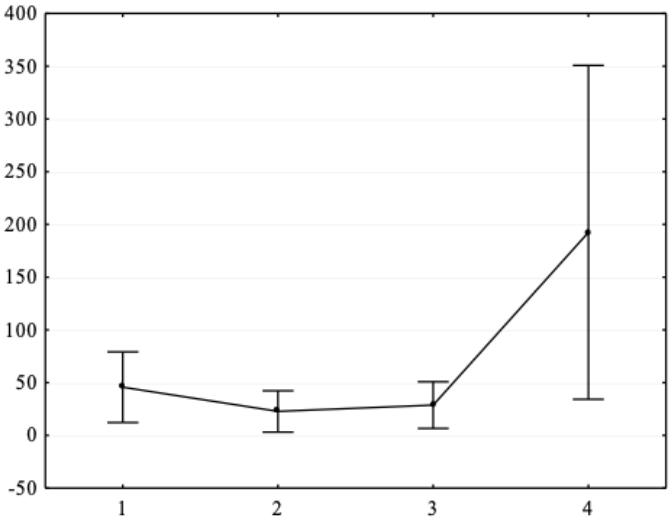

Figure 2. Results of one-way ANOVA (X-axis – independent variable: general intelligence level (1 – intellectually poor, 2 - borderline level, 3 - below average, 4 - average level); Y-axis – dependent variable – spectral power absolute values of the background EEG alpha range in P4 lead, μV2.

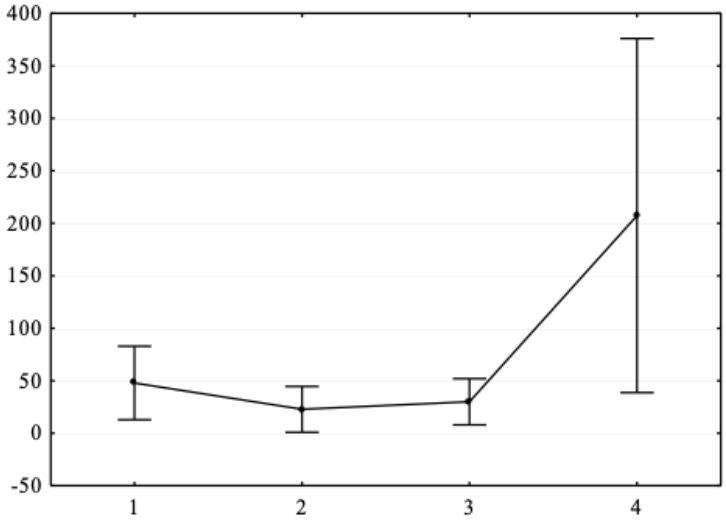

Figure 3. Results of one-way ANOVA (X-axis – independent variable: general intelligence level (1 – intellectually poor, 2 – borderline zone, 3 – below average, 4 – average IQ); Y-axis – dependent variable – spectral power absolute values of the background EEG apha range in Pz lead, μV2.

As a result of one-way analysis of variance, it was found that there are significant differences in the EEG spectral power in adolescents with ASD and mental retardation in the alpha range for P3 ($F = 4.6$, $p < 0.05$), P4 ($F = 3.99$, $p < 0.05$) and Pz ($F = 4.18$, $p < 0.05$) leads. Post-hoc comparisons with Bonferroni correction showed that a higher level of general intelligence corresponds to a higher EEG spectral power in the alpha range (all $p < 0.05$).

Moreover, a higher level of general intelligence corresponds to a higher spectral power of the EEG in the alpha range. As a result of completing the task on complex visual-motor reaction (it was possible to assess the visual-motor reaction time in 31 teenagers), the following indicators were assessed: average reaction time (ms) 666.9±197.6, integral reliability index (IRI) 29.3±25.9, standard deviation (ms) 211.5±101.5, number of anticipations 2.4±3.5, number of incorrect answers 1.4±1.4, number of omissions 2.0±3.1, total number of errors 6.1±6.6, class of sensorimotor reactions 1.9±1.55, assessment of the level of sensorimotor reactions 0.17±0.23. The assessment of the level of sensorimotor reactions showed that seven (23%) adolescents with ASD and mental retardation failed to complete the task during the complex visual-motor reaction test, due to the fact they completed the task too slowly, made a critically large number of errors or did not understand the instructions. Further, the number of adolescents with ASD and mental retardation who completed the complex visual-motor reaction task was distributed as follows: the first (low) class of sensorimotor reactions was detected in eight adolescents (26%), the second (below average) class - in four adolescents (13%), the third (average) class - in six adolescents (19%), the fourth (above average) class - in five adolescents (16%), the fifth (high) class - in one adolescent (3%).

A one-way analysis of variance was performed for the absolute values of the spectral power of the background EEG of different ranges depending on the class of sensorimotor reactions. The results of the conducted one-factor ANOVA on the influence of the class of sensorimotor reactions on the spectral power of the background EEG are presented in Figures 4, 5, 6.

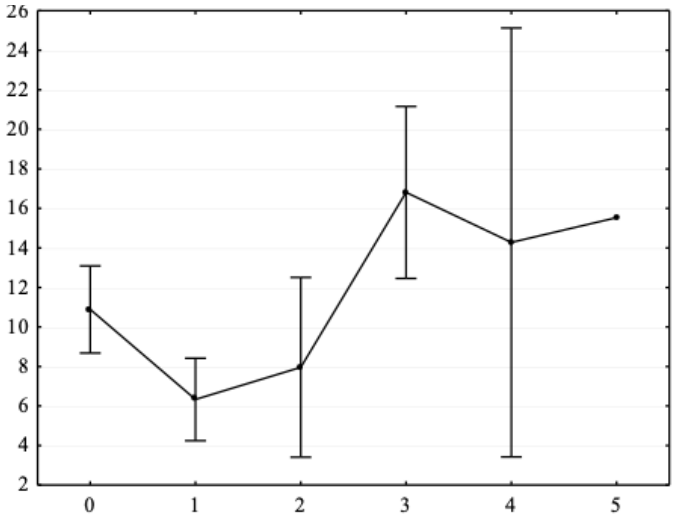

Figure 4. Results of one-way ANOVA (X-axis – independent variable: sensorimotor reaction class (0 – no class, 1 – low, 2 – below average, 3 – average, 4 – above average, 5 – high); Y-axis – dependent variable – spectral power absolute values of the background EEG beta-1 range in O2 lead, μV2.

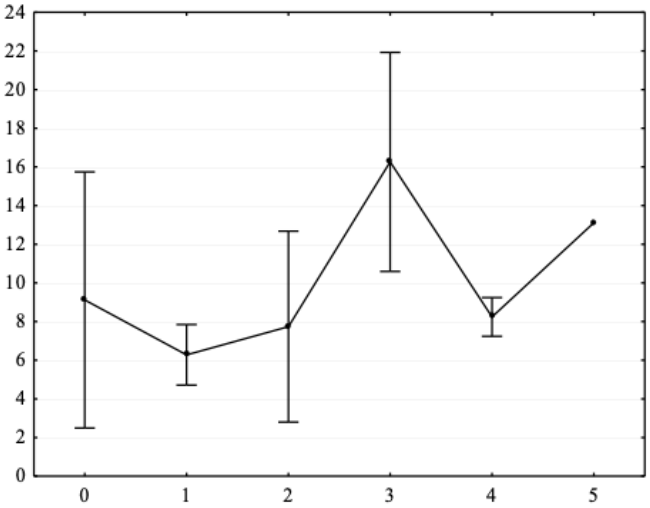

Figure 5. Results of one-way ANOVA (X-axis – independent variable: sensorimotor reaction class (0 – no class, 1 – low, 2 – below average, 3 – average, 4 – above average, 5 – high); Y-axis – dependent variable – spectral power absolute values of the background EEG beta-1 range in Oz lead, μV2.

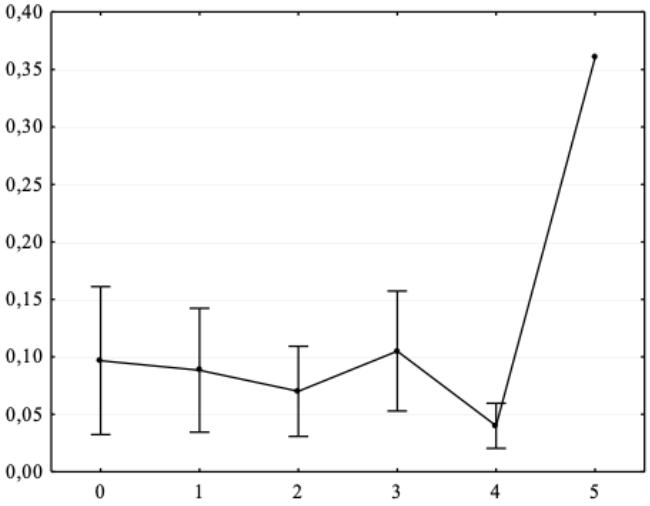

Figure 6. Results of one-way analysis of variance (X-axis – independent variable: sensorimotor reaction class (0 – no class, 1 – low, 2 – below average, 3 – average, 4 – above average, 5 – high); Y-axis – dependent variable – spectral power absolute values of the background EEG beta-2 range in F8 lead, μV2.

The conducted one-factor ANOVA allowed us to determine the parameters of the EEG spectral power in the background of adolescents with ASD and mental retardation: in the beta1 range for O2 ($F = 4.53$, $p < 0.05$) and Oz ($F = 3.18$, $p < 0.05$) leads; in the beta2 range for F8 ($F = 4.81$, $p < 0.05$) lead. Post-hoc analysis with Bonferroni correction showed that the average class of sensorimotor reactions corresponded to higher spectral power values in the beta-1 range; a higher class of sensorimotor reactions corresponded to higher spectral power values in the beta-2 range (all $p < 0.05$).

One-factor ANOVA also showed that, depending on the class of sensorimotor reactions, there were statistically significant differences in the spectral power of the galvanic skin response ($F = 18.8$; $p < 0.01$) and electrocardiogram ($F = 513.31$; $p < 0.01$) data recorded during the background electroencephalogram recording.

Discussions

As shown by the results obtained in this work, a higher level of intelligence corresponds to a higher EEG spectral power in the alpha range for P3, P4 and Pz leads in adolescents with ASD and mental retardation. This may indicate instability of information processing processes, which existing data confirms (Boutros et al., 2015; Arutiunian et al., 2023; Gamirova et al., 2023). In our work, it was found that, according to the parameters of the complex visual-motor reaction, the average class of sensorimotor reactions in adolescents with ASD and mental retardation corresponds to higher values of the EEG spectral power of the beta-1 range for O2 and Oz leads, and a higher class of sensorimotor reactions corresponds to higher values of the spectral power in the beta-2 range for F8 lead. An increase in the parameters of sensorimotor reactions at the EEG level corresponds to an increase in the high-frequency component in the right frontal region in adolescents with ASD and mental retardation, which can be regarded as an increase in the activation of the right frontal cortex.

It was also found in our work that in relation to the parameters of a complex visual-motor reaction, a higher class of sensorimotor reactions corresponds to higher spectral power values of the GSR and ECG, that is, at a higher level of the functional state, the peripheral nervous system is more activated. The higher values of the peripheral nervous system performance indicators in adolescents with ASD and mental retardation obtained in our work are also consistent with the information on the features of its work in these groups of adolescents (Gul et al., 2020).

Conclusions

1. In adolescents with ASD and mental retardation, a higher level of general intelligence corresponds to a higher spectral power of the EEG in the alpha range in the parietal region.
2. Evaluation of the complex visual-motor reaction showed that the average class of sensorimotor reactions in adolescents with ASD and mental retardation corresponds to a higher spectral power in the beta-1 range of the right and central occipital region; a higher class of sensorimotor reactions corresponds to a higher spectral power in the beta-2 range of the right frontal region.
3. A higher class of sensorimotor reactions corresponds to higher spectral power values of the galvanic skin response and electrocardiogram.

Obtained results contribute to the theoretical basis of psychophysiology and psychology of adolescents with ASD and mental retardation. The obtained data is used to draw up a plan for psycho-correctional and psycho-developmental work.

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Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization and methodology, Vorobyeva E.; formal analysis, Rahimova E.; writing—original draft preparation, Vorobyeva E., Rahimova E.; writing—review and editing, Vorobyeva E., Rahimova E.; All authors have read and agreed to the published version of the manuscript.

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Examining the Possibility of Using Visual Programming Language Scratch in Preschool Education for Learning Arithmetic Operations

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Abstract: The aim of the research is to examine the potential of harnessing the visual programming language Scratch for learning arithmethic operations in preschool education as well as to find out wheather a visual programming environment intended for algorithmic thinking development can enhance learning outcomes and contribute to better understanding of arithmetic operations. In the pedagogical experiment, which was realized during two school years, 48 children aged 5 to 6 years were involved. The children were separated into three groups in accordance with the learning method. The traditional method of learning numbers, addition and subtraction was implemented in the first group. The second group of children learned numbers and arithmetic operations using visual programming language Scratch. In the third group a combined method that included the traditional teaching method and the use of the programming language Scratch was applied. The comparison of different methods of learning arithmetic operations in order to determine the difference in children's achievements was performed by using Mann-Whitney test. The research results indicate that children from the experimental group, in which combined learning method was applied, exceed achievements of the other groups. Accordingly, it could be concluded that the application of visual programming language in preschool education represents an extraordinary complement to the traditional method of learning arithmetic operations.

Keywords: *addition, information-communication technologies, preschool age, subtraction, visual programming environment.*

Introduction

Contemporary society also requires contemporary education. As children are surrounded by modern technologies every day, it is important that they also have the appropriate education. Developed countries make extensive use of information and communication technologies (ICT) for educational purposes. In most countries, its introduction in primary education is becoming very important, while the application of ICT in preschool education is neglected (Belenzada, Mićić, Šaponjić and Kojović, 2021).

Bolstad (2004) emphasizes the importance of using modern technologies including ICT in the educational process of early childhood. The potentials of using modern technologies in early childhood include: enhancing children's learning and play experiences, supporting and strengthening professional learning and development, and supporting and strengthening relationships and communication between early childhood interests, parents and other people connected to the child and its closest environment (Bolstad,2004). There is an increasing number of research whose results indicate the importance and advantages of using ICT in early childhood (Belenzada et al., 2021; Bers, 2018; Mamutović, Marković and Stanisavljević Petrović, 2020; Mamutović, Stanisavljević Petrović and Marković, 2021; Masoumi, 2015; Nikulina, 2016).

Today, block-based coding is a widespread tool in teaching computational thinking especially algorithmic thinking (McManus, 2019). Visual programming environments have a potential to be the future of the educational process regarding their beneficial features that provide knowledge acquisition in a

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superior and more novel way. In educational practice visual programming language Scratch is the most often used. Programming in Scratch is block-based programming intended for initial learning of programming and development of algorithmic thinking in children. This visual programming language is increasingly the subject of researches which treat the use of programming languages in lower grades of primary school (Bodaker and Royenberg-Kima, 2023; Fagerlund, Vesisenaho and Häkkinen, 2022; Garcia, 2023; Kalelioğlu and Gülbahar, 2014; Krizsan and Lambic, 2024; Montiel-Cabello and Gomez-Zermeño, 2021; Saez-Lopez and Miyata, 2013; Saez-Lopez, Roman-Gonzalez and Vazquez-Cano, 2016). The results obtained by the aforementioned authors show that computer management skills, logic, learning programming concepts, ability to solve problems, motivation, creativity and active learning could be advanced by harnessing the block-based programming.

There are also studies whose results indicate the possibility and importance of using visual programming environment in early childhood. Examining the role of visual programming tools in the algorithmic thinking development in preschool age is a research aiming to find out the attitude of preschool and younger school age children to programming. Taking into consideration the impact of programming approaches on the development of algorithmic thinking in the research two programing tools Scratch and Lightbot were investigated. In this research the overall conclusion implies that both groups of children had comparable results in the computational thinking development especially algorithmic thinking. Also, they have evolved a positive attitude towards programming (Rose, Habgood and Jay, 2017). Oliveira and Conceição Lopes (2011) carried out research with preschool children in order to understand how six-year-olds communicate and express themselves using new technologies. Scratch was used as a tool to create projects whose content was motivated by stories and poetry that were adapted to the children's age. The authors pointed out that it was a challenge for the children to use Scratch, which encouraged them to use their imagination when animating stories and songs.

Aforementioned results of research on the application of visual programming languages indicate that their harnessing has a progressive impact on achievements in early education. Hence, it is necessary to realize further researches in order to enlarge implementation of new technologies including visual programming languages in preschool educational work. Starting from Piaget's theory of cognitive development (Miočinović, 2002), according to which children in the period of concrete operations, which is reached around the age of 6, can think logically and perform arithmetic operations, and having in mind that the visual programming environment contributes to logical thinking development (McManus, 2019), the idea arose to examine the possibility of improving the learning of arithmetic operations by using a visual programming language Scratch in preschool education.

Materials and Methods

Children aged 5 to 6 attending a preparatory preschool program in the year before starting school participated in a research conducted at the Preschool "Boško Buha" in Vrbas (Republic of Serbia). The examiner is a professional preschool teacher who works daily with the children. The preschool teacher did not know the children before the research began, which ensured objectivity in the assessment process. Having in mind children's age, the research realized with the children's and parents' accordance after they were informed about all the relevant details of the research, including general information about the research, the purpose and objectives of the research, the research tasks, the research methodology, the absence of potential risks and negative consequences of participation in the research, as well as the anonymity of the data collection process. They were also made aware of the fact that participation in the research is voluntary and that they can withdraw at any time without explanation. The method of data processing and publication of research results were presented to them. Finally, they were informed that if they have any objections to the research procedure, who can they contact.

In the research, which was carried out during two school years, 48 children participated. The first part of the research was carried out during June in the 2022/23 school year and 21 children participated in it. The second part of the research was conducted during December of the 2023/24 school year, in which 27 children participated. The research was conducted over two school years with different groups of children in order to check the repeatability of the trend of the results obtained and the conclusions drawn, as well as to increase the size of the research sample. Before starting the research, the degree of children's previous comprehension of numbers, digits, addition and subtraction was determined based

on the pretest results. The pretest was developed according to the Fundamentals of the preschool preparatory program (Tomić, 2000). The expected learning outcomes of this preschool educational program are that children should master the arithmetic operations of addition and subtraction of numbers up to 10, including number 0 in the year before starting school. The standardized tests from the Manual (Mikić and Jovanović, 2019) were used in the assessment process. These tests usually used to assess the knowledge of numbers and arithmetic operations of preschool children. All children solved the pretest simultaneously in the allotted time of half an hour, which was enough for the children to answer on all the questions. Hereafter, the preschool teacher was performed test evaluation on the basis of the Regulations on standards of educational achievements (2024) issued by the Ministry of Education. In this Rules thresholds for a certain level of knowledge are provided. The pretest consists of 31 questions that are divided into three groups.

The first task is composed of 11 questions related to knowledge of numbers up to 10 including number 0. In the first task the children were required to count how many apples they see and to write down the digit that represents that number. If the child counted the apples correctly and wrote the correct digit, the answer was recorded as correct, otherwise as incorrect. The obtained results of the first task of the pretest in both years of research are shown in Table 1. The highest percentage of children (33.3%) showed on the pretest that they knew numbers and digits completely. Also, research results indicate that more than 50%, that is, 64.6% of the children know numbers and digits because they had at most one incorrect answer in this task.

The second task contains 10 questions related to the arithmetic operation of addition. In the second task, the children added numbers up to 10 including number 0. The pretest questions are designed in that way, based on children's answers, it is possible to determine whether the children understand the addition operation based on the commutativity property, as well as the value of the number 0. One example of the second task which includes commutativity property is shown in Figure 1.

Table 1. *Numbers Task- number and percentage of children in both years of the research*

Correct answers	Number of children in June (%)	Number of children in December (%)	Total (%)	Level
11	8 (38.1)	8 (29.6)	16 (33.3)	know completely
10	7 (33.3)	8 (29.6)	15 (31.3)	know
8 - 9	5 (23.8)	2 (7.4)	7 (14.6)	know partially
0 - 7	1 (4.8)	9 (33.4)	10 (20.8)	do not know

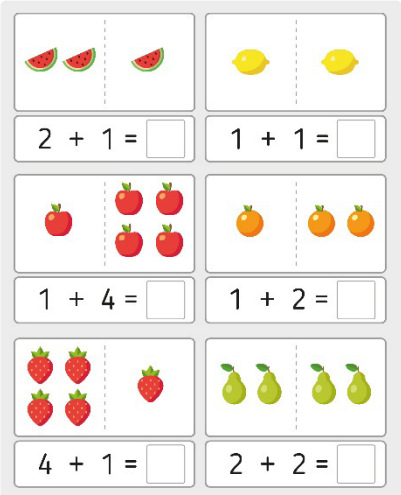

Figure 1. Example of addition task

The results of the second task show that the largest percentage of children (31.2%) partially knows addition, while a quarter knows and 14.6% of them know the addition operation completely (Table 2).

The children subtracted numbers up to 10 including number 0 in the third task. The obtained results are shown in Table 3. One can notice that more than a half of children (56.2%) do not know the subtraction operation. In the first year of the research, no child showed that he/she knows or knows completely

the subtraction operation, while in the second year of the research there was one child who knows the subtraction operation completely and one who gave one incorrect answer.

Table 2. *Addition Task- number and percentage of children in both years of the research*

Correct answers	Number of children in June (%)	Number of children in December (%)	Total (%)	Level
10	3 (14.3)	4 (14.8)	7 (14.6)	know completely
8-9	4 (19)	8 (29.6)	12 (25)	know
3-7	9 (42.9)	6 (22.2)	15 (31.2)	know partially
0-2	5 (23.8)	9 (33.4)	14 (29.2)	do not know

Table 3. *Subtraction Task- number and percentage of children in both years of the research*

Correct answers	Number of children in June (%)	Number of children in December (%)	Total (%)	Level
10	0 (0)	1 (3.7)	1 (2.1)	know completely
8-9	0 (0)	1 (3.7)	1 (2.1)	know
3-7	13 (61.9)	6 (22.2)	19 (39.6)	know partially
0-2	8 (38.1)	19 (70.4)	27 (56.2)	do not know

In the Figure 2 pretest results are shown. Based on all the obtained results of the pretest, sixteen children had all the correct answers in the first task, which means that a third of the children in both years of the research, i.e. 33.3%, know numbers and digits completely. Out of sixteen children, seven children had all the correct answers in the first and second tasks, that is, 14.6% know numbers, digits and addition completely. One can notice that one child had all correct answers in all three tasks in both years of the research.

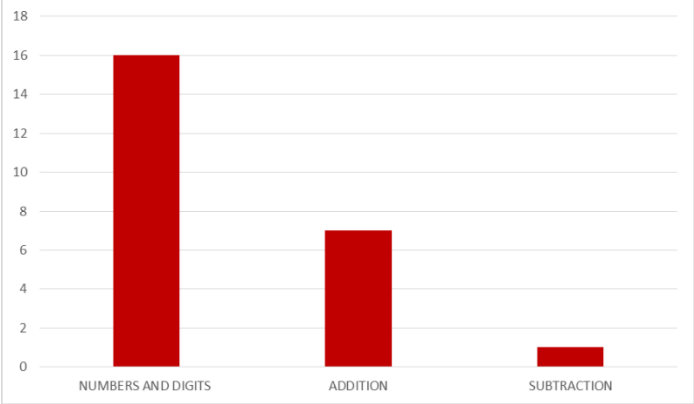

Figure 2. Pretest results

The children were divided into three groups accordingly the pretest results and the confirmed previous knowledge. Kruskal-Wallis test was performed in order to determine whether there were statistically significant differences in prior knowledge between children divided into three groups based on the pretest results. In the Table 4 obtained values of Kruskal-Wallis test for pretest results are given. The obtained H values imply that at significance level $p < .05$ there is no statistically significant difference in the pretest results. Hence, the previous knowledge of arithmetic operations between the groups of children which will learn using various learning methods was equal.

Table 4. *Kruskal-Wallis test for pretest results*

Task	N	H	p
Addition	48	5.467	0.065
Subtraction	48	3.543	0.170

The research lasted four weeks. The children learned arithmetic operations of addition and subtraction three times for 3 hours each week of the research, which is a total of 36 hours of learning over the course of one month. It should be noted that during one 8-hour working day, there were 3 sessions. Each session lasted one school hour, with breaks of about 2 hours between sessions.

The traditional method of learning addition and subtraction was used in the first group of children. During four weeks of learning they did various exercises according to the recommendations from the Fundamentals of the preparatory preschool program (Tomić, 2000). Some of the exercises that were carried out during the research are described below. The second group of children used visual programming language Scratch for learning during four weeks. Some of the exercises with which children from the second group have learned arithmetic operations according to recommendations and instructions (Dikins, Stovel and Melmot, 2018) are described below. In the third group, both approaches to learning arithmetic operations were equally represented. The children learned addition and subtraction up to 10 for 2 weeks using the traditional learning method and did the same exercises as the children in the first group during the first two weeks of the research. In the second part of the research, also for two weeks, the children learned addition and subtraction up to 10 using the visual programming language Scratch and did the same exercises as the children in the second group during the second two weeks of the research.

In the Fundamentals of the preparatory preschool program, it is planned that children overcome operations of addition and subtraction within the first ten (Tomić, 2000). However, most of them, even know how to count, do not know the position of the number in the number sequence and the value of the number. It is especially important that they understand and notice the value of the number 0.

During the research, children in the first and third groups did various exercises from the Fundamentals of the preparatory preschool program (Tomić, 2000) intended for working in a traditional way with children in the year before starting school. These exercises helped them understand and determine the value of a number and its place in a number sequence through play. Also, they did exercises that help them understand and learn the arithmetic operations of addition and subtraction.

One exercise that enables children to understand the value of a number and therefore its place in a number sequence is the following: Chairs are arranged in 3 columns of 5 chairs one behind the other. There are five children in each column standing one behind the other. In this exercise each child is a number from 1 to 5. When they hear the number 5 spoken, the children from all the columns in the place number 5 should find their place on the chair that is fifth in order in the number sequence.

Another exercise that allows children to learn arithmetic operations is the exercise with baskets and objects in them. There are two baskets in front of the children. One is empty and there is one candy in the other basket. By adding and subtracting candies or some other objects such as pencils, felt-tip pens, cubes, balls, etc. from the basket while constantly counting how many are currently in the basket, children determine numbers and adopt addition and subtraction operations on concrete examples using the objects available to them in the study room.

The exercise with cards marked with the numbers from 0 to 10 and the signs +, - and = was implemented for children to learn addition and subtraction operations. The cards are placed in front of the children and they are all mixed up. Children have the task of finding the corresponding card with that number when they hear a number. Then when they hear a plus or minus sign and another number they also need to find the matching cards. After that, they find the = sign and say what the total result of the arithmetic operation is. During this exercise, children add and subtract using their 10 fingers. The exercise is repeated by the children giving each other different combinations of numbers and operations.

Some of the exercises with which children from the second group (learning method using the visual programming language Scratch) and the third group (combined learning method) have learned arithmetic operations are described below. In the first exercise, the children had the task of dragging the addition block and the subtraction block onto the desktop. Children can easily see which blocks they are, they can be recognized by the (+) and (-) signs. Then they enter numbers into the blocks and by clicking on them they get the correct solution to a specific task. Before that, they add or subtract themselves using their

fingers before clicking to see the correct solution which the cat character shows them on the desktop. The children independently gave each other tasks that contained different combinations of numbers for both addition and subtraction.

Also, the previously described exercise with the placement of cards was realized. Children placed cards with different combinations of numbers up to 10 and addition or subtraction operations and then entered these combinations into blocks in the visual programming language Scratch. The children very easily adopted the way in which it is possible to calculate using the cat character. Thus, learning through this method was interesting and easy for them because they were playing and competing with the cat.

Results

After completing the process of learning arithmetic operations of addition and subtraction, the children solve the identical test again as during the initial knowledge assessment.The results of the first task of the test for all three groups are shown in Tables 5,6 and 7. Based on the obtained results, it can be concluded that the children, who studied using the combined method, have the best achievments, i.e. 75% of them in both years of the research showed that know numbers and digits completely, while 56.2% of children that studied using the traditional learning method showed that know numbers and digits completely. Learning in the programming language in the first year of research showed that the largest percentage of children (42.8%) partially know, while in the second year of research 55.5% of children know numbers and digits completely. Also, based on the results obtained, it can be noted that all children who studied using the combined learning method in the first year of the research gave at most one incorrect answer, i.e. that all children know numbers and digits, while when applying the traditional learning method, that percentage is 85.8% and with the programming language Scratch is 57.2%. In the second year of research, 88.9% of children who studied using the combined method knew numbers and digits, while with the traditional method, that percentage was 77.7%, and with the programming language Scratch was 66.6%. Based on the obtained results, it can be noted that the children who learned numbers and digits using the combined learning method in both years of the research reached the best achievements, that is, a total of 93.7% of children know numbers and digits.

Table 5. *Numbers Task- number and percentage of children in the both years of the research (traditional method)*

Correct answers	Number of children in June (%)	Number of children in December (%)	Total (%)	Level
11	3 (42.9)	6 (66.6)	9 (56.2)	know completely
10	3 (42.9)	1 (11.1)	4 (25)	know
8-9	1 (14.2)	0 (0)	1 (6.3)	know partially
0-7	0 (0)	2 (22.3)	2 (12.5)	do not know

Table 6. *Numbers Task- number and percentage of children in the both years of the research (Scratch method)*

Correct answers	Number of children in June (%)	Number of children in December (%)	Total (%)	Level
11	2 (28.6)	5 (55.5)	7 (43.8)	know completely
10	2 (28.6)	1 (11.1)	3 (18.7)	know
8-9	3 (42.8)	3 (33.4)	6 (37.5)	know partially
0-7	0 (0)	0 (0)	0 (0)	do not know

Table 7. *Numbers Task - number and percentage of children in the both years of the research (combined method)*

Correct answers	Number of children in June (%)	Number of children in December (%)	Total (%)	Level
11	5 (71.4)	7 (77.8)	12 (75)	know completely
10	2 (28.6)	1 (11.1)	3 (18.7)	know
8-9	0 (0)	1 (11.1)	1 (6.3)	know partially
0-7	0 (0)	0 (0)	0 (0)	do not know

The results obtained for the second task of the addition operation are shown in Tables 8, 9 and 10. Based on the obtained results, it can be noticed that the children who learned with the traditional learning method showed the worst results in both years of the research, i.e. that 18.7% of them know addition completely, while this percentage is higher among children who learned using the visual programming language Scratch and it was 25%. The best results in both years of the research were shown by children who studied using the combined learning method. In this group, half of the children know addition completely. Also, it can be observed that all children from the third group in the first year of research know the arithmetic operation addition, while in the first group this percentage is 42.9% and in the second only 28.6%. In the second year of research, 66.6% of children who learned using the combined method know the addition operation, 55.6% of the children who learned using the traditional method and less than half of the children (44.5%) who learned using the Scratch programming language know the addition operation. Based on the obtained results, it can be observed that in the group that learned using the combined learning method, there are no children who do not know the addition operation, while in the other two groups there were such children.

Table 8. *Addition Task- number and percentage of children in the both years of the research (traditional method)*

Correct answers	Number of children in June (%)	Number of children in December (%)	Total (%)	Level
10	1 (14.3)	2 (22.2)	3 (18.7)	know completely
8-9	2 (28.6)	3 (33.4)	5 (31.3)	know
3-7	4 (57.1)	2 (22.2)	6 (37.5)	know partially
0-2	0 (0)	2 (22.2)	2 (12.5)	do not know

Table 9. *Addition Task- number and percentage of children in the both years of the research (Scratch method)*

Correct answers	Number of children in June (%)	Number of children in December (%)	Total (%)	Level
10	1 (14.3)	3 (33.4)	4 (25)	know completely
8-9	1 (14.3)	1 (11.1)	2 (12.5)	know
3-7	4 (57.1)	4 (44.4)	8 (50)	know partially
0-2	1 (14.3)	1 (11.1)	2 (12.5)	do not know

Table 10. *AdditionTask- number and percentage of children in the both years of the research (combined method)*

Correct answers	Number of children in June (%)	Number of children in December (%)	Total (%)	Level
10	4 (57.1)	4 (44.4)	8 (50)	know completely
8-9	3 (42.9)	2 (22.2)	5 (31.3)	know
3-7	0 (0)	3 (33.4)	3 (18.7)	know partially
0-2	0 (0)	0 (0)	0 (0)	do not know

The results for the third task are shown in Tables 11, 12 and 13. The highest percentage of children in both years of the research showed that they partially know the arithmetic operation subtraction. In the first year of the research, this percentage in the group that learned using the traditional learning method was 85.7%, while in the group that learned using the combined method, it was 57.1%, and among the children who learned using the Scratch programming language, it was 42.8%. In the second year of the

research, children in the first and third group have the same results, that is, 55.6% of children partially know the subtraction operation. The application of the visual programming language Scratch gave the worst results because the largest percentage of children (44.4%) do not know the subtraction operation. The best results in both years of the research were shown by children who learned using the combined method, as 37.4% of them show that they know the operation of subtraction, while in the first group that percentage is 12.5% and in the second 25%. In the second group 12.5% of children and in the third group 18.7 % know subtraction completely, while in the first group no child knows subtraction completely.

Table 11. *Subtraction Task- number and percentage of children in the both years of the research (traditional method)*

Correct answers	Number of children in June (%)	Number of children in December (%)	Total (%)	Level
10	0 (0)	0 (0)	0 (0)	know completely
8-9	1 (14.3)	1 (11.1)	2 (12.5)	know
3-7	6 (85.7)	5 (55.6)	11 (68.8)	know partially
0-2	0 (0)	3 (33.3)	3 (18.7)	do not know

Table 12. *Subtraction Task - number and percentage of children in the both years of the research (Scratch method)*

Correct answers	Number of children in June (%)	Number of children in December (%)	Total (%)	Level
10	2 (28.6)	0 (0)	2 (12.5)	know completely
8-9	0 (0)	2 (22.2)	2 (12.5)	know
3-7	3 (42.8)	3 (33.4)	6 (37.5)	know partially
0-2	2 (28.6)	4 (44.4)	6 (37.5)	do not know

Table 13. *Subtraction Task- number and percentage of children in the both years of the research (combined method)*

Correct answers	Number of children in June (%)	Number of children in December (%)	Total (%)	Level
10	2 (28.6)	1 (11.1)	3 (18.7)	know completely
8-9	1 (14.3)	2 (22.2)	3 (18.7)	know
3-7	4 (57.1)	5 (55.6)	9 (56.3)	know partially
0-2	0 (0)	1 (11.1)	1 (6.3)	do not know

The 25-th percentile, median and 75-percentile for all three tasks in both years of the research are shown in Tables 14, 15 and 16. One can observed that children who learned numbers and arithmetic operations using the combined method reach the best results in terms of 25-th percentile, median and 75-percentile.

Table 14. *Traditional method*

Task	25-th percentile	Median	75-th percentile
Numbers	10	11	11
Addition	4.5	7.5	9
Subtraction	3	4.5	6

Table 15. *Scratch method*

Task	25-th percentile	Median	75-th percentile
Numbers	9	10	11
Addition	4	5.5	9.75
Subtraction	1.25	3	8.5

Table 16. *Combined method*

Task	25-th percentile	Median	75-th percentile
Numbers	10.25	11	11
Addition	8.25	9.5	10
Subtraction	5.25	7	8.75

Figure 3 shows a comparative view of the results for all three groups in the first year of research. Based on all the obtained results, it can be concluded that the children from the third group who learned using the combined method outperform acievements in the other two groups of children. The obtained results show that all children in the third group know or completely know numbers, digits and the operation of addition, and 42.9% of them know the operation of subtraction, because each one gave a maximum of two incorrect answers. The obtained results reveal that the children have overcome the subtraction operation the worst in all three groups, but even in this case, the children who learned using the combined method again outperform achievements of children in the other two groups, that is, slightly less than half of the children (42.9%) know the subtraction operation.

Figure 4 shows a comparative view of the results for all three groups in the second year of the research. Based on all the obtained results, it can be concluded that the children from the third group who learned using the combined method reached the best achievements. The obtained results show that 88.9% of children from the third group know or completely know numbers and digits, two-thirds of children (66.6%) know or completely know the operation of addition and a third of children (33.3%) the operation of subtraction because they all gave maximum of two incorrect answers. The obtained results show that the children from all three groups have overcome the subtraction operation the worst, but that even in this case, the children who learned using the combined method again outperform achievements of children in other two groups, that is, a third of the children (33.3%) know the subtraction operation.

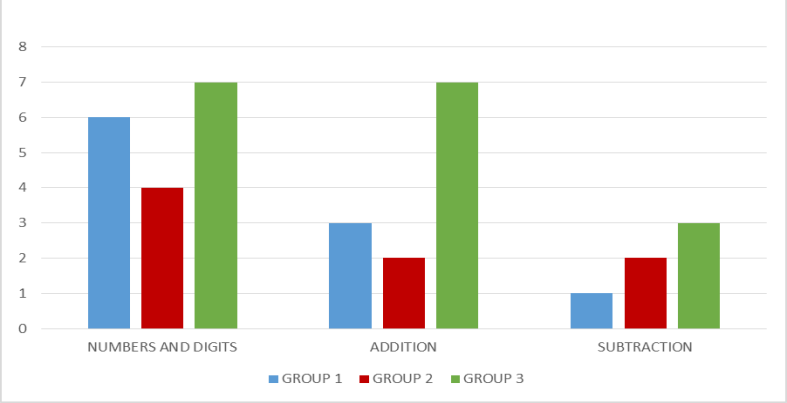

Figure 3. Results in the first year of research

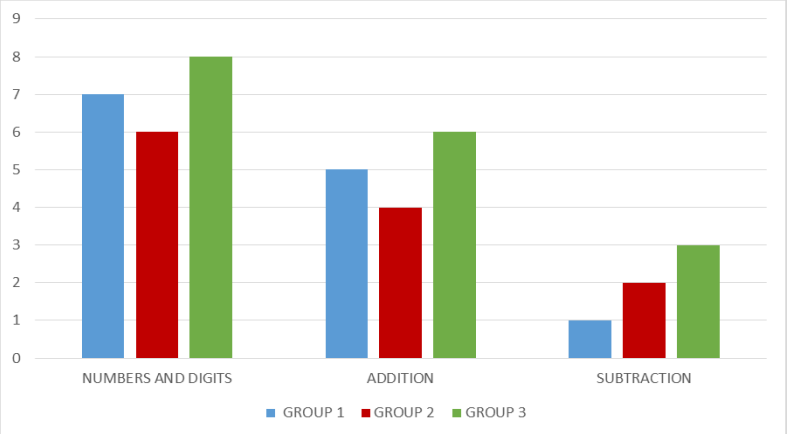

Figure 4. Results in the second year of research

Table 17. *Kruskal-Wallis test for test results*

Task	N	H	p
Addition	48	8.067	0.018
Subtraction	48	7.296	0.026

In the Table 17 obtained values of Kruskal-Wallis test for test results are given. The obtained H values reveal that at significance level $p < .05$ there is statistically significant difference in the effect of these three methods on the mastering of the arithmetic operations in children of preschool age.

Table 18 shows Skewness and Kurtosis values for all three groups and both arithmetic operations.

Table 18. *Skewness and Kurtosis for all three groups*

	I		II		III	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Addition	1.078	3.437	-0.146	1.870	-1.564	5.067
Subtraction	-0.265	2.381	0.449	1.735	-0.311	2.624

Having in mind sample size (N<20) and results of Skewness and Kurtosis test, it was decided to use a non-parametric test. The comparison of different learning methods in order to determine the achievement differences was done on the basis of the Mann-Whitney U test results. The measure for children's achievement in mastering arithmetic operations was the number of correct answers. The software package SPSS was used to perform the Mann-Whitney U test and calculate the p-value. Below is the null hypothesis in the Mann-Whitney U test for different tasks and groups being compared:

1. There is no statistically significant difference in the distribution of the number of correct answers when comparing the traditional (I) and Scratch (II) method of learning addition.
2. There is no statistically significant difference in the distribution of the number of correct answers when comparing the traditional (I) and Scratch (II) method of learning subtraction.
3. There is no statistically significant difference in the distribution of the number of correct answers when comparing the traditional (I) and combined (III) method of learning addition.
4. There is no statistically significant difference in the distribution of the number of correct answers when comparing the traditional (I) and combined (III) method of learning subtraction.

The comparative view of the Mann-Whitney U test results for the traditional (I) and Scratch (II) method of learning arithmetic operations is given in Table 19. The obtained U values imply that at significance level $p < .05$ there is no statistically significant difference in the effect of these two methods on the mastering of the arithmetic operations. Hence, the null hypothesis is accepted for both arithmetic operations. Also, the findings reveal the possibility of using the visual programming language Scratch in preschool education for learning arithmetic operations having in mind that children who learned in this way showed similar results as children who learned using a well-established traditional learning method.

For both arithmetic operations, the practical significance of the research results was examined, and in that purpose the effect size - Cohen's coefficient was determined. In the Table 19, it can be noticed that d=0.2 for addition and d<0.2 for subtraction which means that effect size is small for both arithmetic operations.

Table 20 gives the comparative view of the Mann-Whitney U test results for the traditional (I) and combined (III) method of learning arithmetic operations. The values of the obtained U tests (U=65.50, p= .016) are statistically significant at level $p< .05$ and imply that the combined (III) learning method has statistically better effects on the adoption of the arithmetic operation addition. Furthermore, combined (III) method has statistically better impact in mastering the arithmetic operation subtraction (U=59, p=.008), even at a significance level of $p< .01$. Thus, the null hypothesis is refused and the alternative hypothesis is accepted for both arithmetic operations. The findings reveal that the blend of well-established traditional learning method and the potential of the visual programming language Scratch for developing algorithmic thinking enables reaching the best achievments regarding outcomes of learning arithmetic operations in preschool age.

Table 19. *Comparison of the traditional (I) and the Scratch (II) method of learning arithmetic operations addition and subtraction*

	I		II		M-W U test		
	MR	N	MR	N	U	p	d
Addition	17.41	16	15.59	16	113.50	.590	0.20
Subtraction	16.94	16	16.09	16	121.50	.809	0.02

N-Number of children; MR-Mean Rank

Table 20. *Comparison of the traditional (I) and the combined (III) method of learning arithmetic operations addition and subtraction*

	I		III		M-W U test		
	MR	N	MR	N	U	p	d
Addition	12.59	16	20.41	16	65.50	.016	0.91
Subtraction	12.19	16	20.81	16	59.00	.008	1.05

N-Number of children; MR-Mean Rank

For both arithmetic operations, the practical significance of the research results was examined, and the effect size - Cohen's coefficient was determined. In the Table 20, it can be noticed that d>0.8 and effect size is large for both arithmetic operations, which shows that there is a practical significance of the determined better effect of combined (III) method in comparison with the traditional (I) method in mastering the arithmetic operations of addition and subtraction.

The research findings show that the combined method is the most effective for learning arithmetic operations of addition and subtraction in preschool education. On the other hand, it has been shown repeatedly that learning arithmetic operations only using the visual programming language Scratch is less effective than the traditional or combined learning method. The reason for these findings could be the fact that Scratch is primarily intended for younger school age children and is not suitable for independent use in preschool age, but in combination with a well-established traditional learning method, it reveals its potential and enables the best achievements, thereby contributing to the improvement of learning arithmetic operations in preschool education. It should be noted that there are researches that also indicate the benefits of using the visual programming language Scratch for learning mathematics in general (Fauziah, Rahayu and Putri, 2024; Imawati and Shubchan, 2018; Sarifah, Nugroho, Marini, Yarmi, Safitri and Dewiyani, 2023), but the aforementioned researches relate to improving learning outcomes for lower elementary school students. Fauziah et al. (2024) studied the impact of implementing the Scratch-assisted problem based learning model on mathematical comprehension ability and also came to the conclusion that Scratch contributes to improving ability compared to the traditional learning model. Research findings (Imawati and Shubchan, 2018) showed that using of Scratch proved to be effective in helping students to understand mathematics. Sarifah et al. (2023) recommends using Scratch-based interactive games in order to increase interest in learning matematics in second grade of elementary school. On the other hand, there are researches related to examining the potential of programming for learning mathematics in general in preschool education. Somuncu and Aslan (2022) determined that the programming has a significant effect on mathematical reasoning skills of chlidren. In the research regarding the impact of project-based learning and visual programing language Scratch on the achievements of preschool children in mastering of arithmetic operations, authors (Sovilj-Nikić and Marinković, 2024) indicate that visual programming language Scratch is an exceptional supplement to the project-based learning of arithmetic operations. Palmer (2017) also indicates to the extraordinary potential of using programming to teaching mathematics in preschool education.

The results of this research reveal that subtraction is more complicated arithmetic operation than addition for children in all three groups. However, it could be noticed that no child knows the subtraction operation completely in the first group, while in the other two groups there are children who know subtraction completely. These findings may indicate the potential of the visual programming language Scratch in supporting the learning of subtraction.

The effect size shows that obtained results have also practical significance and could stimulate cur-

riculum developers to implement the visual programming language Scratch in preparatory preschool programs for learning arithmetic operations in addition to the already established traditional learning method. Also, these findings may encourage investments in ICT equipment of preschools as well as further informal education of preschool teachers regarding application of visual programming languages and ICT in general.

Conclusions

Listening to the children and following their interests and needs to learn something completely different in the educational work in the preschool institution, the idea arose to use the visual programming language Scratch for learning numbers, digits and arithmetic operations of addition and subtraction. The obtained values of U tests are statistically significant and reveal that the children from the experimental group, in which the combined learning method was applied, outperform achievements of children in the other two groups in both years of the research. Also, it could be observed that the subtraction operation is the worst mastered in both years of the research in all three groups. But, even in this case, the children who learned using the combined method again reached the best achievements, i.e. more than a third of the children knew the subtraction operation after learning.

The results of this research lead to the conclusion that the harnessing of the visual programming language Scratch in preschool education is an excellent complement to the traditional learning method. Also, during the research, it was observed that children think logically through algorithms by using the visual programming language Scratch which enables them to acquire new knowledge and understand mathematical and logical concepts through play. It should also be noted that there are certain limitations to the research conducted. Based on the test results, it was determined that children who learned using the combined learning method have better achievements than the other two groups at the time of testing, immediately after the implementation of the teaching content. Therefore, in further research, it would be desirable to examine whether this method is also more effective in terms of the durability of knowledge.

Finally, it should be emphasized that the visual programming language Scratch is primarily intended for younger school age and that the findings of this research reveal the potential of harnessing the visual programming language Scratch to improve the learning of arithmetic operations in preschool age, which certainly represents a new and unique contribution of this research and a good basis for further research. In future, it would be useful to examine the effectiveness of using this method for learning content from other areas in order to determine whether the visual programming language Scratch is also an exceptional complement to the traditional method of learning other teaching topics in preschool education, which would enable the generalization of the results obtained.

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Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, S.S.N. and J.Ć.; formal analysis S.S.N.; investigation J.Ć.; methodology, S.S.N. and J.Ć.; visualization S.S.N.; writing—original draft preparation, S.S.N.; writing—review and editing, S.S.N.. All authors have read and agreed to the published version of the manuscript.

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Young Teachers' Perceptions of Professional Self-efficacy and the Implementation of the Pedagogical Referendum Program

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Abstract: The professional self-efficacy of young teachers plays a crucial role in shaping the quality of education and student outcomes. However, limited research has explored how self-efficacy perceptions are influenced by pedagogical reform initiatives. Addressing this gap, the present study aims to assess young teachers' professional self-efficacy perceptions and evaluate their perspectives on the implementation of the pedagogical reform program. Employing mixed-methods research design, data were collected from a sample of 418 teachers. Quantitative data were gathered using the Teacher Self-Efficacy Scale, while qualitative insights were obtained through semi-structured interviews developed by the researchers. Quantitative data were analyzed using statistical software, and qualitative data were examined through descriptive analysis. Findings indicate that young teachers exhibit a high level of professional self-efficacy, with no significant differences observed across gender or teaching discipline. Additionally, while many participants reported a moderate understanding of the pedagogical reform program, they expressed positive attitudes toward professional growth under the mentorship of experienced educators. These results suggest that structured mentorship and targeted professional development initiatives within the pedagogical reform framework can further enhance teachers' self-efficacy and instructional competencies.

Keywords: *young teachers, teacher competence, pedagogical reform, self-efficacy, perception.*

Introduction

The quality of teachers has an important role in the success of education systems. Especially in the first years of the profession, the professional adaptation of teachers and the development of their competencies are one of the main factors affecting both individual and institutional success (Darling-Hammond et al., 2019). Young or new teachers often face many challenges such as classroom management, effective teaching strategies, student evaluation methods, and professional identity formation (Schlebusch, Bhebhe, and Schlebusch, 2024). These challenges show that their professional competency development processes are dynamic and multidimensional.

One of the main factors affecting the professional competence of young teachers is the perception of self-efficacy (Goldag, 2020). Self-efficacy refers to the belief that individuals can perform a certain task (Schunk and DiBenedetto, 2020). Teachers with high self-efficacy can cope with the challenges they face more effectively and develop their pedagogical skills more quickly. In addition, external factors such as mentoring and peer support have a great positive effect on professional development processes.

The self-efficacy of teachers is greatly influenced by their gender, which has an impact on a variety of experience areas and has consequences for professional development and educational practices. Teaching effectiveness is impacted by gender differences in self-efficacy, which is defined as beliefs in one's ability to carry out necessary actions to attain particular levels of performance (Marshall (1996)).

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According to research, male educators can show more confidence in their ability to present information and use disciplinary measures, whereas female educators frequently show better self-efficacy in parenting and inclusive teaching practices (Wahyudiati et al., 2020).

Research on creative self-efficacy indicates that gender disparities affect teachers' perceptions of their abilities to foster students' creativity, with significant variances in average and variability (He and Wong, 2021). Because of these differences, instructors and women may choose distinct pedagogical approaches that are tailored to their self-efficiency beliefs; this might result in varied instruction strategies. Whitcomb et al. (2020), for instance, discovered that female engineering students at universities displayed distinct self-efficacy profiles in contrast to their male counterparts, suggesting potential differences in the outcomes of instruction driven by gender.

Furthermore, Henderson et al. (2020) highlight how curriculum innovations might influence scientific education by highlighting the necessity for physics teachers to identify these gender-based self-efficiency assumptions. In the end, it is critical to comprehend these subtleties to create thorough professional development programs that accommodate the varying degrees of self-efficacy among genders and support fair learning settings for all students (Wahyudiati et al., 2020).

The increasing influence of technology in educational environments is also transforming the professional competence development processes of young teachers (Volkov and Chikarova, 2021). Digital platforms and learning management systems offer teachers opportunities to develop and implement new teaching techniques (Darling-Hammond, Hyler and Gardner (2017)). For example, McKnight et al. (2020) emphasized that digital tools strengthen teachers' pedagogical adaptation skills, which increases the quality of teaching.

Innovative approaches and support programs are of great importance in the development of professional qualifications. Innovative platforms such as INTHRN facilitate the professional adaptation processes of young teachers by offering special solutions to their needs through digital mentoring applications (Darling-Hammond et al., 2019). In addition, structured professional development programs improve teachers' skills in classroom practices and increase their commitment to the education system (OECD, 2021).

The pedagogical referendum, which was carried out as a condition for the professional adaptation of young teachers based on the innovative platform created by INTERN, aims to support the adaptation processes of teachers who are new to the profession. It is extremely important to develop models that aim to accelerate the professional development of young teachers under the guidance of an experienced mentor and to facilitate their integration into the educational environment (Smith and Ingersoll, 2004). In this context, the initiative aims to facilitate both individual and professional development through an innovative platform known as INTHRN.

The challenges faced by newly graduated teachers during their transition into professional practice represent a significant issue impacting the overall quality of education. When teachers are not provided with appropriate guidance and support during their professional adaptation, burnout and loss of motivation can occur (Ingersoll, 2012). The pedagogical referendum model offers an effective strategy to solve these problems. According to research, mentoring programs play an important role in increasing the professional competence and self-confidence of young teachers (Fantilli and McDougall, 2009).

This project will enable young teachers to adapt to professional life more easily by implementing the pedagogical referendum model. The INTHRN platform aims to increase teachers' professional skills and motivation, thus improving the quality of education. Innovative approaches will enable future teachers to be more equipped and more effective (OECD, 2021).

The development levels of young teachers' professional competencies have created a wide area of research in terms of teacher education and professional development processes. Studies conducted in this context have covered topics such as professional adaptation, self-efficacy, the role of technology, and the impact of mentoring programs. Some studies conducted in the field are as follows: Tschannen-Moran and Hoy (2001) examined the characteristics of effective teacher professional development programs and concluded that young teachers rapidly develop their pedagogical skills with practical learning experiences. Kraft and Papay's (2020) study, which addresses the relationship between supportive environments in teachers' workplaces and their professional development, revealed that a positive working environment in the early years of the profession increases teachers' performance. Schunk and DiBenedetto (2020), based on self-efficacy theory, emphasized that social and emotional learning plays an important role in

the process of developing teachers' professional competencies. McKnight et al (2020) examined the effects of digital tools on improving teachers' pedagogical practices and concluded that digital technologies facilitate classroom management and assessment processes. Geeraerts, Tynjälä, and Heikkinen (2020) addressed the contribution of intergenerational learning to the professional development of teachers and stated that young teachers adapt quickly by learning from their experienced colleagues.

Klassen and Chiu (2010), based on motivational theories, showed that teachers develop their professional competence more quickly when their self-efficacy perception is high. OECD's (2021) global report examined the effects of the lifelong learning approach on teachers and stated that professional development programs increase the competence levels of teachers. Makhsutova, 2024 study, which examined the effect of emotional intelligence on teacher self-efficacy, concluded that colleague support and job satisfaction strengthen teacher competencies. Schlebusch, Bhebhe and Schlebusch, 2024 study on technology integration revealed that teachers can respond to student needs more effectively in professional development processes supported by digital tools. In a study based on the learning approach, Reitano and Green (2013) showed that teachers effectively used learning processes from their experiences and thus improved their professional competence.

Makhsutova concluded in her study (Kraft and Papay, 2020) that by focusing on the factors shaping the self-efficacy of English Foreign language (EFL) teachers, it is necessary to contribute to the theoretical understanding and practical improvement of teacher training programs in Kazakhstan. In their study, Yuce et al. (2024) found that Turkish and Kazakh EFL teachers had similar perspectives on the effects of culture on online learning self-efficacy, but differed on the feelings, challenges, factors, and strategies related to this topic.

Within the scope of the information listed so far, there is a need and a research gap to evaluate the program to train young teachers, such as INTHRN, together with the self-efficacy of the teachers, both for the implementation of the program and to reveal the self-efficacy of young teacher.

Purpose of Research

The purpose of this research was to determine the professional self-efficacy perceptions of young teachers and to evaluate their views in the context of the implementation of the pedagogical referendum program.

In this direction, the following research questions and hypotheses were created,

Research Question 1. What level of knowledge do the young teachers participating in the research have about the pedagogical referendum program?

Research Question 2. What are the perspectives of the educators involved in the research on the enhancement of professional development for novice teachers under the mentorship of an experienced educator?

Research Question 3. What are the views of the teachers participating in the research regarding the development of their professional competencies in the context of the implementation of the pedagogical referendum program?

H_1: The professional qualifications of young teachers are at a moderate level.

H_2: The professional qualifications of young teachers differ according to the gender variable.

H_3: The professional competencies of young teachers differ according to their fields of expertise.

Materials and Methods

Research Method

This study was structured as mixed-method research. Mixed method research is characterized by the integration of perspectives from researchers adhering to a singular research paradigm, those employing a situational research paradigm, and those embracing a pragmatic research paradigm within a mixed methodology. This approach yields more comprehensive data by integrating quantitative and qualitative methodologies (Rossman and Wilson, 1985). This study assessed the professional competencies of novice educators using a quantitative approach. The perspectives of novice educators regarding the advancement of their professional competences within the framework of the pedagogical referendum program were assessed using qualitative methodology. The results were collectively assessed and conveyed to the audience.

Participants

The study group consisted of 418 teachers. The teachers were actively working in various schools in Kazakhstan in the 2024-2025 academic year. All teachers participating in the study were in the first year of their profession. Table 1 presents the demographic characteristics of teachers.

Table 1. *Demographic distribution of teachers*

	f	%
Gender		
Female	233	55.7
Male	185	44.3
Total		
Branch		
Class Teacher	91	21.8
Math Teacher	85	20.3
English Teacher	82	19.6
Geography Teacher	81	19.4
Science Teacher	79	18.9
Total	418	100

In Table 1, 55.7% of the young teachers participating in the research are female and 44.3% are male. 21.8% of the teachers are classroom teachers, 20.3% are mathematics teachers, 19.6% are English teachers, 19.4% are geography teachers and 18.9% are science teachers.

Instruments for Data Acquisition

The research data were collected utilizing two separate data collection devices. The initial instrument is the "Teacher Self-Efficacy Scale" created by Hooper, Caughlan and Mullen (2013). The measure comprises three sub-dimensions: "student participation," "teaching strategies," and "classroom management," along with 24 items. The scale's linguistic modification was executed. The second data collecting instrument is the semi-structured interview format. The researchers devised the semi-structured interview format.

Study on Language Equivalence of the Teacher Self-Efficacy Scale

The translation process of the Teacher Self-Efficacy Scale, intended for adaptation to Kazakh, was initially executed during the linguistic equivalence study. At this juncture, two proficient linguists, well-versed in both languages, translated the original version of the scale into Kazakh. Efforts were made to guarantee that the translation had the same meaning as the original text. The Kazakh version was developed based on translations considered suitable by language specialists. After two weeks, the scale, translated into Kazakh, was reverted to its original language by language experts. Consequently, the discrepancies between the reverse-translated version and the original version were examined. The scale, translated into Kazakh for the final time after two weeks, was compared with the preceding translation. The definitive Kazakh version of the scale was developed in accordance with the consensus of the two linguistic specialists. The translations were evaluated considering professional comments, resulting in the creation of a provisional Kazakh form.

The pilot application phase commenced following the translation phase. A sample group for the pilot implementation of the scale was established. The sample group comprised 271 young educators. There were 144 female teachers and 127 male teachers. The educators involved in this segment of the research were excluded from the primary sample group of the study. A sample size of 271 students satisfied the threshold of five times the amount of items necessary for factor analysis research (Child, 2006). The trial application was implemented in classrooms where the educators provided instruction.

Subsequent to the pilot application, exploratory factor analysis was conducted on the acquired data set. The SPSS 25.0 statistical software was utilized at this step. The initial phase involved assessing if the scale utilized in the linguistic equivalence study exhibited a normal distribution. The Kolmogorov-Smirnov test was favored for assessing normality. The analysis of the data set indicated a normal distribution (p=.059>.050).

All components of the scale were utilized for exploratory factor analysis. The initial objective was

to ascertain the adequacy of the sample size. The Kaiser-Meyer-Olkin (KMO) test yielded a result of 0.79, exceeding 0.70, indicating that exploratory factor analysis is applicable to the data. Subsequently, Bartlett's Sphericity test was conducted. Bartlett's Sphericity test ($\chi 2 = 548.665$, $p < .001$) indicated that exploratory factor analysis was applicable to the data. At this juncture, the eigenvalue was ascertained to be 1, and the factor structure of the scale was analyzed. In the main component analysis, it was seen that all items in the original three-factor structure of the scale corresponded to the factors in the translated version, and no items were eliminated from the scale. The factors accounted for 75.9% of the variation rate. The scree plot was analyzed, revealing a maximum loading value of 0.859 and a minimum loading value of 0.544.

Subsequent to this research, confirmatory factor analysis was conducted on the scale. The SPSS Amos 25.0 statistical software was utilized at this stage. The goodness of fit indexes were assessed for confirmatory factor analysis. The model fit was assessed using the metrics of $\chi 2$/df (Chi-Square/Degree of Freedom), NNFI (Non-Normed Fit Index), and RMSEA (Root Mean Square Error of Approximation). The analysis yields the following values: $\chi 2$ /df= 2.144 (p=.000), NNFI=.92, and RMSEA=.055. Hooper, Caughlan and Mullen (2013) proposed a $\chi 2$ /df value of less than 5, a NNFI value beyond .80, and an RMSEA value below .080. In light of this perspective, it was concluded that the scale maintained its original structure within Kazakh culture and was relevant. Table 2 presents the item factor loadings and Cronbach's Alpha coefficients for the Teacher Self-Efficacy Scale, finalized using confirmatory component analysis.

Table 2. *Teacher Self-Efficacy Scale item factor loadings*

Article	Expression on Scale	Item Total Correlation	Cronbach's Alpha
Student Participation Sub-Dimension			
1	How successful are you in reaching difficult students?	,750	
2	How much can you get students to think critically?	,846	
3	How can you motivate students who show little interest in lessons?	,795	
4	How much can you do to convince students that they can succeed in school?	,859	
5	How can you make students value learning?	,839	,788
6	How can you help students develop their creativity?	,766	
7	How can you help an unsuccessful student understand the lesson better?	,820	
8	How much support can you provide to families to help their children succeed in school?	,781	
Teaching Strategies Sub-Dimension			
9	How well can you answer students' difficult questions?	,640	
10	How well can you evaluate whether students have grasped what you have taught?	,633	
11	To what extent can you prepare questions that will enable you to evaluate your students well?	,644	
12	How can you ensure that lessons are appropriate to each student's level?	,729	
13	To what extent can you use different assessment methods?	,705	
14	How many alternative explanations or examples can you provide when students are confused?	,625	,849
15	How well can you implement different teaching methods in the classroom?	,691	
16	How can you provide a suitable learning environment for highly talented students?	,680	
Classroom Management Sub-Dimension			
17	How successful are you in controlling behaviors that negatively impact the lesson in the classroom?	,572	
18	How clearly can you state your expectations for student behavior?	,561	
19	How well can you ensure that classroom activities run smoothly?	,544	
20	How well can you ensure that students follow classroom rules?	,568	
21	How can you calm down students who are disrupting the lesson or making noise?	,577	
22	How well can you create a classroom management system that suits different groups of students?	,604	,835
23	How well can you prevent a few problem students from disrupting the course?	,611	
24	How well can you deal with students who disregard you?	,590	
	Teacher Self-Efficacy Scale Cronbach's Alpha	822	,

Table 2 presents the item-total correlations and Cronbach's Alpha coefficient for the Teacher Self-Efficacy Scale, which was modified for data collection in the research. In the reliability examination of the 3-factor structure of the scale, Cronbach's Alpha values were determined to be .788 for the student engagement sub-dimension of the Teacher Self-Efficacy Scale, .849 for the teaching techniques sub-dimension, and .835 for the classroom management sub-dimension. The Cronbach's Alpha score for the Teacher Self-Efficacy Scale was determined to be .822 overall. The scale employs a 5-point Likert format. In this grading system, the score intervals are regarded as uniform. The range of 1.00 to 1.80 is classified as Very Little; the range of 1.81 to 2.60 is classified as Little; the range of 2.61 to 3.40 is classified as Somewhat; the range of 3.41 to 4.20 is classified as Somewhat Much; and the range of 4.21 to 5.00 is classified as Much.

Semi-Structured Interview Framework for the Pedagogical Referendum Program for Young Educators

The semi-structured interview instrument developed to gather qualitative data for the study has three questions. Two language specialists reviewed these open-ended questions, and their assessments on grammatical structure were considered. Following the requisite amendments, the open-ended questions were presented to four educators for the assessment of their clarity. The educators deemed the questions lucid and comprehensible. The four teacher candidates involved in this evaluation segment of the study were omitted from the sample group. The semi-structured interview questions were posed in person to 40 teachers randomly chosen from the study's sample group. The researchers created structured interview questions to align with the research questions.

Procedure for Data Acquisition

The study's quantitative data were gathered by administering the scale to teachers in person, within the school setting, and collectively. The qualitative data for the study were obtained via face-to-face interviews with 40 teachers randomly chosen from the sample group. Quantitative and qualitative data were gathered concurrently. The compilation of research data required around seven weeks. The duration for administering the Teaching Profession Attitude Scale is established at 20-25 minutes, whereas the Teacher Semi-Structured Interview Form requires 10-15 minutes for completion.

Adherence to Ethical Standards

A study ethics consent form was developed for all experts and educators who participated in the scale adaption, semi-structured interview form preparation, and data collection phases of the research. The consent form indicated that the research's objective was to ensure personal data confidentiality and prohibit its usage in any other studies. The participants who received the consent form signed the voluntary participation document, affirming their voluntary involvement in the research. Moreover, data collection procedures were conducted with the awareness and consent of the institutions involved at every stage of the research. During the writing phase of the research, ethical standards were adhered to.

Analysis of Data Collection

The study's quantitative data were analyzed using the SPSS 25.0 statistical software. The Kolmogorov-Smirnov test, which assesses the normality assumption of parametric statistical methods, was utilized in the data analysis procedure. Consequently, it was determined to implement parametric tests on the data set. The normal distribution of the dataset was ascertained. Alongside standard deviation and weighted average computations, an independent samples T-test was utilized for bivariate data analysis, while one-way ANOVA was employed for the examination of multiple variables. The study's significance threshold was established at 0.05. The descriptive analysis technique was employed in the examination of qualitative data. Marshall (1996) asserted that the objective of descriptive analysis is to systematically organize and evaluate data acquired through observation or interviews for presentation to the reader. The perspectives of educators on the advancement of their professional competences within the framework of the pedagogical referendum program were converted into findings using descriptive analysis.

Results

In this part of the research, the professional attitudes of young teachers were determined and their views on the development levels of their professional competencies in the context of the implementation of the pedagogical referendum program were evaluated.

Findings Regarding the Teacher Self-Efficacy Scale

Table 3 presents the sub-dimensions of the Teacher Self-Efficacy Scale for the participating teachers, along with the weighted means and standard deviations for the overall scale.

Table 3. *Weighted means and standard deviations of the scale*

Scales	M	SD
Student Participation Sub-Dimension	4.08	0.690
Teaching Strategies Sub-Dimension	4.11	0.677
Classroom Management Sub-Dimension	4.01	0.658
Teacher Self-Efficacy Scale	4.05	0.675

Table 3 outlines the various sub-dimensions of the Teacher Self-Efficacy Scale, along with the weighted means and standard deviations for the overall scale. The calculations for the weighted means and standard deviations were conducted for the Student Participation Sub-Dimension (M = 4.08, SD = 0.690), Instructional Strategies Sub-Dimension (M = 4.11, SD = 0.677), Classroom Management Sub-Dimension (M = 4.01, SD = 0.658), and the overall Teacher Self-Efficacy Scale (M = 4.05, SD = 0.675). The results indicate that teachers exhibit a notably high level of self-efficacy in both the sub-dimensions of the Teacher Self-Efficacy Scale and the overall scale.

Table 4 presents the T-test results of the Teacher Self-Efficacy Scale scores of the teachers participating in the study according to the gender variable.

Table 4. *T-test results according to gender variable*

Gender	N	M	SD	F	p
Female	233	4.12	0.677	4,116	,260
Male	185	3.96	0.651		

Table 4 presents the scores from the Teacher Self-Efficacy Scale for the educators involved in the study, along with the outcomes of the independent variables t-test based on the gender variable. The analysis revealed no notable difference in the self-efficacy of teachers based on gender (F=4.116, p>0.5). The levels of self-efficacy among female and male teachers in relation to their professions were observed to be comparable.

Table 5 presents the results of the One-Way Analysis of Variance (ANOVA) for the Teacher Self-Efficacy Scale scores among the teachers involved in the study, categorized by the branch variable.

Table 5. *One-way analysis of Variance (ANOVA) results according to branch variable*

Class	N	***M***	**SD**	**F**	**p**
Class Teacher	91	4.07	0.861		
Math Teacher	85	4.12	0.880		
English Teacher	82	3.99	0.810	4,672	0.280
Geography Teacher	81	4.05	0.843		
Science Teacher	79	4.01	0.829		

Table 5 presents the findings from the One-Way Analysis of Variance (ANOVA) concerning the Teacher Self-Efficacy Scale scores among the educators involved in the study, categorized by the branch variable. No notable distinction was observed in the self-efficacy of the educators in relation to the branch variable (F=4.672, p>0.5). Research indicated that educators across various disciplines, including class-

room instruction, mathematics, English, geography, and science, exhibited comparable levels of self-efficacy in their respective professions.

Findings Regarding the Semi-Structured Interview Form Regarding the Young Teachers' Pedagogical Referendum Program

Table 6 categorizes the knowledge levels of young teachers participating in the research regarding the pedagogical referendum program.

Table 6. *What level of knowledge do you have about the pedagogical referendum program?*

Category	F	%
Very High	2	5
High	7	17.5
Middle	26	65
Low	4	10
Very Low	1	2.5
Total	40	100

Table 6 shows the knowledge levels of the young teachers participating in the research regarding the pedagogical referendum program under 5 categories. 5% of the young teachers responded as very high, 17.5% as high, 65% as medium, 10% as low and 2.5% as very low.

Table 7 presents the perspectives of the young educators involved in the study concerning the enhancement of their professional growth through the mentorship of a seasoned professional.

Table 7. *What are your views on accelerating their professional development under the guidance of an experienced mentor?*

Category	F	%
I support it very much	6	15
I support	30	75
I partially support it	3	7.5
I don't support	1	2.5
I Don't Support It at All	-	-
Total	40	100

Table 7 presents an evaluation of the perspectives of the young teachers involved in the research regarding the enhancement of their development with the support of an experienced mentor, categorized into five distinct areas. 15% of the young teachers answered "I support it very much", 75% "I support it", 7.5% "I partially support it" and 2.5% "I do not support it". There is no teacher among the young teachers who participated in the research who answered "I do not support it at all".

Table 8 categorizes the views of the young teachers participating in the research on the development of their professional competencies in the context of the implementation of the pedagogical referendum program.

Table 8. *What are your views on the development of professional competencies in the context of the implementation of the pedagogical referendum program?*

Category	F	%
I find it very developmental	8	20
I find developers	28	70
I find it partly developmental	3	7.5
I don't find any developers	1	2.5
I don't find any developers	-	-
Total	40	100

Table 8 categorizes the perspectives of young teachers involved in the research regarding the enhancement of their professional competencies within the framework of the pedagogical referendum

program into five distinct categories. In the research, 20% of young teachers indicated that they find it very developing, 70% reported it as developing, 7.5% considered it partially developing, and 2.5% did not find it developing. None of the young teachers who participated in the research indicated that they do not find it developing at all.

Table 8 categorizes the perspectives of young teachers involved in the study regarding the enhancement of their professional competencies within the framework of the pedagogical referendum program into five distinct categories. In the research, 20% of young teachers indicated that they find it very developing, 70% reported it as developing, 7.5% considered it partially developing, and 2.5% did not find it developing. None of the young teachers who participated in the research indicated that they do not perceive any developmental benefits.

Discussion

The professional competence levels of the teachers involved in the study were assessed based on their responses to the sub-dimensions of the Teacher Self-Efficacy Scale and the overall scale. In this context, weighted means and standard deviations were computed for the Student Participation Sub-Dimension, Instructional Strategies Sub-Dimension, Classroom Management Sub-Dimension, and the overall Teacher Self-Efficacy Scale. The results indicate that teachers exhibit a high level of self-efficacy in both the sub-dimensions and the overall Teacher Self-Efficacy Scale. The study by Tschannen-Moran and Hoy (2007) corroborated this finding. The study indicated that teachers' perceptions of self-efficacy significantly influence their professional performance and student success. Berdousis (2024) found that individuals with extensive technological backgrounds demonstrated higher self-efficacy. Ongoing engagement in professional development significantly enhanced confidence, underscoring its importance in digital pedagogy.

The self-efficacy of the young teachers participating in the study was evaluated according to the gender variable. The findings revealed that the self-efficacy of female teachers and male teachers was at similar levels. A study conducted by Skaalvik and Skaalvik (2010) emphasized that gender did not have a significant effect on teacher self-efficacy and that occupational stress and student behaviors affected this perception more. Similarly, Schwarzer and Hallum (2008) stated that self-efficacy levels did not show a gender difference, but that supportive factors in the work environment were more decisive.

The self-efficacy of the young instructors involved in the study was assessed based on the branch variable. The results indicate that educators in classroom instruction, mathematics, English, geography, and science exhibit comparable levels of self-efficacy in their respective fields. Friedman and Kass (2002) stated that the differences in self-efficacy depending on the branch depend on individual factors rather than the pedagogical approaches of the teachers. Bandura (2012) stated that the perception of self-efficacy is related to the general motivation level and support systems of individuals, regardless of the branch.

The majority of young educators involved in the study reported possessing a moderate understanding of the pedagogical referendum program. Young teachers' views on the acceleration of their professional development under the guidance of an experienced mentor were also found to be positive. Hobson et al. (2009) emphasized that effective mentoring programs accelerate the professional development of teachers. In addition, Lindgren (2005) stated that new teachers increase their self-efficacy levels thanks to mentoring. Similarly, Butabayeva et al. (2025) aimed to validate the teaching competence scale for inclusive practices as an evidence-based approach that would allow for further decisions in their research. Validation processes confirmed the reliability of use in Kazakhstan. Considering these findings, they discussed the implications for sustaining and improving inclusive practices in Kazakhstan. They specifically highlighted the improved impact of teacher experience and increased training on perceived teacher engagement; the perceived practices of behaviour management used; and how these were achieved through the introduction of new 'relaxed' inclusive schools and their focus on education.

The majority of young teachers who participated in the study stated that their professional competence could be improved in the context of the implementation of the pedagogical referendum program. Kennedy (2016) emphasized that pedagogical development programs are effective in improving teachers' classroom management and student achievement. Darling-Hammond (2010) stated that pedagogical programs strengthen teachers' self-efficacy perceptions.

When the findings obtained from the research were compared with the results of the research conducted in the field, it was observed that the research findings were consistent in international literature.

Conclusion

The definitions of the teacher's role in the implementation of the learning process and guiding students to develop their skills vary from period to period. In many countries around the world, with the integration of developing technologies into education, teacher training programs have focused on training teachers who will meet the needs of the 21st century. Therefore, this study aimed to determine the professional competencies of young teachers and to evaluate their views on the development levels of their professional competencies in the context of the implementation of the pedagogical referendum program. The study concluded that the professional self-efficacy of the young instructors included was significantly high. The professional self-efficacy of the young teachers participating in the study was evaluated according to the gender variable and their branches. The findings revealed that the gender and branch variables did not create a significant difference in the self-efficacy of the young teachers. The majority of the young educators involved in the study indicated that they possessed a moderate understanding of the pedagogical referendum program. The views of the young teachers regarding the acceleration of their professional development under the guidance of an experienced mentor were also found to be positive. The majority of the young teachers participating in the study stated that their professional competencies could be developed in the context of the implementation of the pedagogical referendum program.

Recommendations

Despite the research findings indicating a high level of professional competence among instructors, it is essential to maintain the continuity of professional development programs. Mentoring programs should be established where experienced teachers guide young teachers and this process should be made systematic. Mentoring can strengthen young teachers' perceptions of competence. The promotion of pedagogical referendum programs should be increased. The research indicated that the level of knowledge of young teachers regarding pedagogical referendum programs is at a moderate level. Therefore, young teachers should be given more information about the scope and implementation processes of these programs. These suggestions will contribute to the further development of young teachers' professional competence and to the improvement of the quality of educational environments.

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Transparency

The author asserts that the text is candid, accurate, and transparent, indicating that no essential elements of the investigation have been excluded and that any deviations from the original study design have been elucidated. This study adhered to all writing ethics.

Competing Interests

The author states that there are no conflicts of interest associated with the publication of this paper.

Author Contributions

Project administration, G.Y.; Conceptualization, H.U.; methodology, H.U.; formal analysis and Coding, G.Y. and R.N.N.; writing—original draft preparation, S.S.G. and Z.N.A.; writing—review and editing, H.U. and G.Y. All authors have read and agreed to the published version of the manuscript.

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Development of Scientific Writing and Communication Skills in the Context of Forestry Research

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Abstract: This article is devoted to the investigation and experimental validation of a model for developing scientific writing and communication skills among students majoring in "Forestry". The study included a scientometric analysis of scientific publications using CiteSpace software, which revealed key areas of research such as argumentation, inquiry-based writing, scientific communication, and metacognitive components. In parallel with the analytical work, a pedagogical experiment was carried out, involving students from both experimental and control groups. The skills were assessed across eight aspects: formulation of the scientific problem, text structuring, source citation, clarity and logical coherence, use of scientific vocabulary, data interpretation, visualization of results, and justification of conclusions. The results demonstrated a significant improvement (on average, 35%) in all components among students in the experimental group, while the control group showed minimal changes. This confirms the effectiveness of the practice-oriented model, integrated into the educational process through research-based tasks. The findings can be applied in the development of educational programs and methods for training forestry specialists.

Keywords: *scientific writing, scientific communication, research competencies, CiteSpace, forestry education, pedagogical experiment.*

Introduction

Relevance and problem statement

In recent years, the term "scientific writing and communication" has been increasingly used in the scientific and educational environment to refer to the set of skills necessary for the effective presentation and dissemination of research results. The development of these skills is becoming particularly important in the context of increasing demands on academic publication activity and the rapid development of the digital environment of scientific interaction.

In the context of the modernization of education and the emphasis on practice-oriented learning, the formation of students' research competencies is becoming an integral part of staff training. It is especially important to develop students' ability to clearly and logically present the results of scientific activity, use accepted standards of scientific design, interact with the professional community, and form analytical and reasoned texts. All this contributes not only to improving the quality of specialist training, but also to their integration into the international scientific space.

This work is aimed at studying approaches to the development of scientific writing and communication skills among students involved in research, as well as at identifying relevant areas and scientific

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clusters in this field. The research examines both pedagogical strategies (PBL, PBL, STEM, inquiry-based learning) and digital tools that contribute to the formation of written and oral scientific speech.

Despite the growing interest in the development of scientific writing and communication in general, there is a clear shortage of research on this topic in the context of forestry and the training of forestry specialists. This conclusion is confirmed by the results of a scientometric analysis of publications indexed in the Web of Science database conducted using CiteSpace software (Chen, 2006). The analysis showed that the key terms “scientific writing”, “science communication”, and “academic writing” are mostly found in publications related to medicine, engineering, general pedagogy, and biology. At the same time, publications related to forestry education or forest science students are presented in fragments and do not form stable scientific clusters.

In this regard, there is a need for a comprehensive analysis of existing pedagogical approaches, as well as the development and implementation of models that contribute to the effective formation of students’ scientific communication skills within the framework of real research projects. This study seeks to fill the identified scientific and practical gap, relying both on scientometric analysis using CiteSpace and on experimental testing of a practice-oriented model for the formation of scientific writing among forestry students.

The state of educational programs in the field of forestry in Kazakhstan

Despite the existence of educational programs in the field of forestry in Kazakhstan, the quality of specialist training faces certain challenges. More than 100 forestry specialists graduate in Kazakhstan every year. According to the Ministry of Science and Higher Education of the Republic of Kazakhstan, about 60% of university graduates do not work in their specialty, which indicates that there is no link between personnel training and the economic needs of the region (Zakon.kz, n.d.). Those who get a job in the field of forestry are often not involved in research activities, as this is not provided for by their job responsibilities. A significant part of forestry workers do not have specialized education, which is due to low wages and lack of social support, which reduce the attractiveness of work in this industry (Ishekenova, 2024).

According to the data of the National Chamber of Entrepreneurs of the Republic of Kazakhstan “Atameken”, educational programs in the direction of B079 “Forestry” are implemented in 8 universities located in 7 cities of the country (Atameken, n.d.). However, such programs are mainly focused on theoretical disciplines, and practical training is limited to short periods of academic and industrial practice.

Foreign experience in training specialists

In developed countries, educational programs in the field of forestry are based on the close integration of scientific research, practice and innovation. Students are involved in project activities, ecosystem monitoring, laboratory work, and modeling of natural processes. Special attention is paid to critical thinking, interdisciplinary approach and academic writing as part of the educational paradigm. This approach allows future specialists to be prepared for the challenges of sustainable natural resource management (University of British Columbia, 2024).

Approaches to the formation of scientific writing and communication

The development of scientific writing and communication skills is a prerequisite for the professional growth of future scientists and specialists. Effective scientific communication promotes integration into the academic community, participation in international projects and the promotion of scientific results in society (Brownell, Price, and Steinman, 2013; Faber et al., 2024).

Structured educational programs play an important role in the formation of these competencies. One example is the Scientific Communication program, which is based on the principles of high-level thinking training (HOLS) and supports the development of clear presentation and argumentation skills (Scherz, Spektor-Levy, and Eylon, 2005; Suparman and Darmawan, 2022; Juarez and Kenet, 2018). Academic writing courses are increasingly being introduced in universities, where students learn to formulate hypotheses, structure articles, and prepare scientific reports. Additionally, resources such as The Craft of Scientific Communication provide practical tools for improving academic writing skills (Harmon and Gross, n.d.).

The inclusion of such courses in undergraduate and graduate programs contributes to improving the quality of education, particularly in the context of globalizing scientific knowledge. Programs at institutions like Duke University and Stanford effectively integrate theoretical foundations with practical assign-

ments and publication training (Willems-Jones et al., 2019; Jude, 2017).

Integration of students into real scientific research

The integration of students into real scientific research is a transformative educational approach that promotes deeper learning and engagement in science (Dounas-Frazer, Ríos, and Lewandowski, 2019). Programs such as Students as Researchers (STARs) enable students to conduct proactive research in both school and university settings, fostering responsibility and sustained interest in scientific work (Silverman, 2012).

Authentic forms of research—such as research internships, student-teacher-scientist partnerships, field-based practices, and participation in citizen science—facilitate student comprehension of scientific methodology, critical thinking, and data analysis skills (Okhotina and Belonogova, 2021; Edwards et al., 2007; Bailenson, 2013; Strogetskaya and Betiger, 2024; Anop and Petruk, 2014; Ovsepyan, 2019).

STEM-based strategies, integration of project activities, and experiential learning approaches further enhance student engagement and prepare them for professional scientific practice (Kanematsu and Barry, 2016; Jackson, 2013).

Using CiteSpace to analyze scientific clusters

CiteSpace software, a tool for citation analysis and visualization of scientific information, was used to identify directions and trends in the research field. This tool enables the tracking of key publications forming scientific clusters, identification of highly cited authors, and construction of co-authorship networks (Chen, 2006; Chen, 2020; Chen et al., 2010).

The conducted scientometric analysis showed that the most active research on the topic of scientific communication is concentrated in the fields of medicine, pedagogy, and engineering. Topics related to the training of forestry students are poorly represented and require further development in both research and applied aspects.

Materials and Methods

A. Data sources

For the scientometric analysis, data from the Web of Science Core Collection (WOSCC) database, an authoritative international source of scientific information, including peer-reviewed publications, was used. The sample included publications from the Science Citation Index Expanded (SCI-EXPANDED) and Emerging Sources Citation Index (ESCI), as they cover a wide range of disciplines, including education, ecology, forestry, and interdisciplinary research.

The search for publications was conducted in March 2025 through the advanced Web of Science interface. To improve the accuracy of the sample, the logical operators AND, OR, as well as a phrasal search in quotation marks "..." were used. Queries were applied to the following fields of publications: Title, Abstract, and Author Keywords. This made it possible to identify works that address the topics of scientific writing and communication in the context of forestry education.

Examples of search queries:

1. "scientific writing" OR "science communication" AND "forestry education";
2. ("academic writing" OR "research skills") AND ("forestry educatio" OR "environmental education").

The following terms were used as keywords:

scientific writing, science communication, academic writing, research skills, student engagement, forestry education, environmental education, scientific literature, publication ethics, STEM communication.

The analysis period covers 2021-2024. The data for 2025 were excluded from the analysis because they were not yet fully available in the Web of Science database at the time of the analysis.

Criteria for inclusion of publications:

- the language of publication is English;
- type of publications - original articles, reviews, editorial materials, conference abstracts, letters;
- full-text accessibility and relevance to the research topic.

As a result of applying these criteria, the analysis included 77 publications corresponding to the intersection of scientific writing and educational practices in the field of forestry. All selected publications

were exported to a CiteSpace-compatible format for further analysis of scientific clusters, terms, author networks, and time trends.

B. Analysis tool

To analyze the scientific literature, *CiteSpace* software was used, which is specifically designed to visualize and analyze structural relationships between scientific publications (Chen, 2006). *CiteSpace* enables the identification of key clusters, influential authors, dominant topics, and emerging trends through co-citation and temporal analysis.

The following functions were used in the research:

- clusterization of scientific publications;
- analysis of citation spikes;
- assessment of the centrality of nodes in the network (by degree and by intermediacy);
- calculation of Sigma, a significance indicator that combines citation and centrality;
- building thematic and author networks.
- Analysis Parameters:
- type of analysis: co-citation;
- the level of analysis: document – author – keywords;
- intervals: 1 year each;
- cluster labeling method: LLC, LSI, MI;
- minimum citation threshold: 3;
- visualization is saved in PNG format.

C. Methodological justification

The application of the scientometric approach with the help of CiteSpace has allowed:

- to systematize existing publications;
- identify key clusters and missing areas;
- to assess the relevance and scientific richness of the topic;
- to substantiate the need for further research in the context of the formation of scientific research competencies among students of forestry.

Table 1. *Search queries*

Source	Web of Science Core Collection
Citation databases	SCI-EXPANDED, ESCI
Time coverage	2021 – 2025
Language	English
Document types	Article
Search stages	Search query
#1	TS = (“scientific writing” OR “academic writing” OR “science communication” OR “research writing” OR “scientific literacy” OR “publication literacy” OR “research communication” OR “writing skills” OR “presentation skills” OR “academic discourse” OR “research competence”)
#2	TS = (“forestry education” OR “forest science” OR “forest research” OR “forestry students” OR “environmental education” OR “natural resources education” OR “forest ecology” OR “sustainable forestry”)
#3	#1 AND #2

Note: #1 - the stage of literature search on scientific writing and communication;
#2 - the stage of searching for literature related to forestry and research;
#3 - a combined query to identify relevant publications at the intersection of the two directions.

Statistical analysis

The data were obtained from the Web of Science (WOS) database in the "Full Record" and "Cited References" formats in March 2025. The final sample consisted of 77 publications, which were carefully checked for duplicates, preprocessed, and then imported into CiteSpace software—an advanced platform for documentary data mining and visualization developed by the team of Chaomei Chen (Chen, 2006).

The CiteSpace program combines the methods of social network analysis and cluster analysis, which provides the construction of structural and thematic maps of scientific publications. The analysis examined fundamental knowledge, limitations in research, key topics, the evolution of trends, as well as networks of scientific collaboration, networks of co-authorship and citation.

To ensure reproducibility and reliability of the analysis, the network reduction and filtering parameters used (in particular, the Pathfinder method) were fixed. The CiteSpace 5.8 R1 version was used in the work, which allowed for consistent and reliable processing of the collected data.

Research Methodology

Based on the analysis of scientific literature and modern pedagogical approaches, a practice-oriented model for the formation of students' research competencies in the field of "Forestry" has been developed and tested. The model combines theoretical and practical components and is aimed at developing the skills of scientific writing, communication and independent research activities.

The model includes the following stages: organizational, theoretical, practical, final and effectiveness assessment stages. During the implementation process, the methods of field research, project work, scientific writing, as well as methods of self-reflection and expert assessment were used.

The aim of the research is to substantiate and implement a model that promotes the formation of research competencies among students in the framework of educational and scientific activities.

Objectives:

- to analyze methodological approaches to the formation of research competencies;
- to develop a step-by-step structural model;
- to integrate the model into the educational process in the field of "Forestry";
- to conduct a pedagogical experiment and evaluate its effectiveness.

Table 2. *Description of the model*

№	Stage	Contents
1	Organizational	Formation of control and experimental groups
2	Theoretical	Seminars on scientific writing, data analysis and preparation of scientific texts
3	Practical	Field trips (core collection, analysis of annual rings, visual inspection of trees)
4	Final	Conducting a scientific seminar with a presentation of the results, discussion
5	Effectiveness assessment	Scales of assessment of motivation, cognitive, procedural, practical and reflexive components are used (see below)

To strengthen the academic part, a new discipline was introduced, the work curriculum "Organization and planning of research work", in which students mastered the tools of scientific writing, methods of publication activity and the basics of research ethics.

Diagnostic and assessment methods

To assess the formation of students' research competencies, a set of diagnostic methods was used, covering motivational, cognitive, procedural, practical and reflexive components.

1. Motivational component.

To measure the level of educational and research motivation, A. Mehrabian's modified methodology was used, adapted to the educational context. It allowed us to determine the students' internal attitude towards achieving academic and scientific goals.

2. Cognitive component

The assessment of the level of intellectual development and the ability to think scientifically was carried out using a mental development test (intellectual diagnostics) aimed at identifying logical, analytical and abstract thinking.

3. Procedural and practical components

To diagnose the ability to plan and perform research activities, the following methods were used:

- expert assessment of research and project work (abstracts, reports, posters);
- results of students' participation in competitions and scientific conferences;
- monitoring the implementation of practical tasks;
- analysis of laboratory and field work results;
- special professionally oriented tests aimed at testing applied research skills.

4. Reflexive component

The level of awareness of one's own research path and self-assessment of skills was monitored using the S.A. Budassi self-assessment methodology, which includes scales of reflection and professional orientation.

Experiment

The pedagogical experiment was conducted within the framework of the scientific project AP25794101 "Study of the influence of technogenic factors and climate change on tree species growing in industrial regions of Eastern Kazakhstan using the dendroindication method" (2025–2027), implemented under the grant funding program "Zhas Galym" of the Ministry of Science and Higher Education of the Republic of Kazakhstan. The project is coordinated by postdoctoral researcher K.B. Alipina and covers both forestry and environmental aspects of sustainable nature management. The students involved in the project had the opportunity to participate in real scientific research, which ensured the practical application of the model.

The participants of the experiment

129 students participated in the experiment. The Experimental group (EG) included students involved in research and field activities. The Control group (CG) was trained according to the traditional program. The details are provided in table 3.

Table 3. *Number of students in the Experimental and Control groups*

University	Course	Experimental		Control	
		Male students	Female students	Male students	Female students
S. Amanzholov East Kazakhstan University	2	5	18	5	17
S. Amanzholov East Kazakhstan University	3	3	19	4	17
D. Serikbayev East Kazakhstan Technical University	2	9	5	11	4
D. Serikbayev East Kazakhstan Technical University	3	4	2	3	3
Total		65		64	

Stages of the pedagogical experiment

1. Ascertaining stage: determining the initial level of research competencies;
2. Formative stage: model implementation, participation in field work, seminars on scientific writing, project assignments;
3. Control stage: final diagnostics, project protection and analysis of the dynamics of competence development.

Criteria for assessing effectiveness

- motivational – interest in scientific activity;
- cognitive – knowledge and understanding of the scientific process;
- procedural – the ability to perform the stages of research;
- practical – the ability to apply research methods;
- reflexive – the ability to introspect and evaluate results.

Methods of processing the results: Student's t-test, correlation analysis (the relationship between activity level and diagnostic results).

Results and Discussion

A. Geographical distribution of publication activity in the field of scientific writing and communication

As part of this study, a scientometric analysis of publications indexed in the Web of Science Core Collection (WOSCC) database was conducted using CiteSpace software (version 6.1.R6). The sample includes publications for the period from 2021 to March 2025, corresponding to the topics "scientific writing", "academic writing", "science communication", "research skills", "forestry education" and "environmental education".

The key countries were identified based on the affiliations of the authors of the publications selected by an extended search query in the fields Title, Abstract and Author Keywords. Each country was ranked by the number of publications and the number of citations. The analytical sample included 77 publications that meet the search criteria. CiteSpace allowed us to identify the countries whose researchers have made the greatest contribution to the development of the topic, and automatically distributed them into thematic clusters.

The study included publications indexed in the Science Citation Index Expanded (SCI-EXPANDED) and Social Sciences Citation Index (SSCI) databases included in the Web of Science Core Collection (WOSCC). The sample includes original scientific articles, review articles, editorial materials, conference materials, and scientific notes. The Scopus database was not used in the analysis. When calculating bibliometric indicators, the citation of individual publications was taken into account, rather than journals as a whole.

Spain has demonstrated sustained activity (4 citations, cluster № 6), especially in the development of written scientific communication. Australia (3 citations, cluster № 2), Mexico and Germany (2 citations each) also demonstrated involvement in the topic related to student participation in scientific publications and educational projects. The participation of France, South Africa, Ukraine and Switzerland is interesting, each of which appears in the network as an important participant in individual clusters.

In terms of centrality, Switzerland showed the highest value (0.14, cluster № 0), which indicates its role as a link between various research topics and areas. This is followed by Germany (0.06) and Mexico (0.05), which also play an important role in the formation and dissemination of scientific information.

Index of Sigma - reflecting a combination of citation bursts and centrality - amounted to 1.00 in all the leading countries, including Switzerland, Germany, USA, Russia, China, Spain, Australia and others. This highlights the equal importance of their contributions to the subject under study.

Nevertheless, when analyzing the content of the publications, it was found that not a single study has been identified that is directly related to the development of scientific writing and communication skills specifically in the context of forestry. This indicates a clear gap in international research practice and underlines the relevance of the tasks set in this work.

Thus, the results obtained reflect global involvement in the development of academic literacy and scientific writing, but at the same time indicate the need to form a new direction focused on training specialists in the field of forestry with a high level of research and communication competencies.

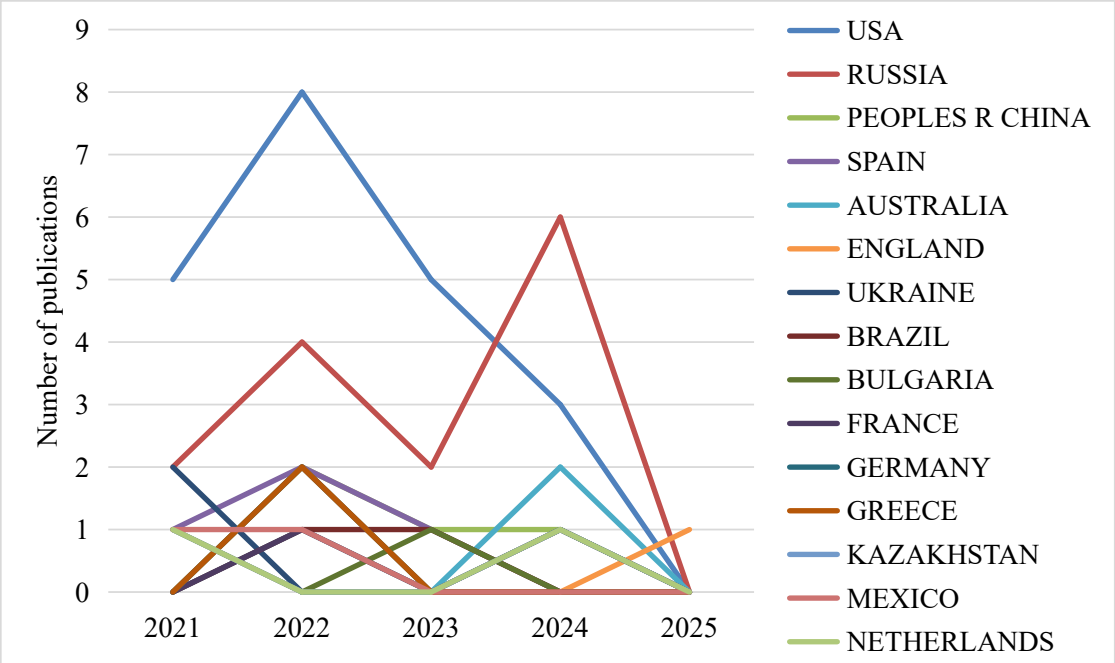

Figure 1. *Analysis of the cluster of distribution countries (Atameken, n.d.)*

B. Thematic areas related to scientific writing and communication

1) Main research directions

Figure 2 is a graph of the common occurrence of keywords, in which each node corresponds to a specific term related to scientific writing, academic and research training. The size of the nodes reflects the importance of the keywords, and the links between them indicate the frequency of their sharing in scientific publications. Cluster analysis technology using the Pathfinder pruning method was used to visualize the structure of thematic areas.

Based on the data analysis, six main clusters were identified, reflecting the dominant trends in the scientific literature. The largest cluster (cluster #0) covers keywords such as “scientific writing”, “global research”, “higher education” and “students”, which emphasizes active attention to the issues of preparing students for research activities in the context of global change. It includes 15 publications and is characterized by a high silhouette coefficient (1.0), which indicates its high coherence.

The second largest cluster (#1) is associated with the topics “scientific communication” and “plant science”, reflecting an interest in the development of scientific communication in the context of crop production and, in our case, can be interpreted as related to environmental education and popularization of climate change and forest conditions.

Cluster #2 is associated with supporting the development of students’ research skills, especially in biomedical sciences, which resonates with the environmental aspects of adaptation of living organisms to external influences, including technogenic factors.

Cluster #6 also deserves attention, which includes such important aspects as “critical thinking”, “communication skill” and “argument driven inquiry” - the skills necessary to analyze the effects of climate and anthropogenic changes on tree ecosystems, especially in the process of preparing research students.

The cluster analysis data indicate that topics related to scientific writing, critical thinking, student research, and forestry are actively developing and are of high importance in the context of modern scientific research. This underlines the importance of developing an interdisciplinary approach in teaching the integration of methods of analyzing climatic and technogenic factors into the educational process, especially in the framework of training specialists in the field of forestry.

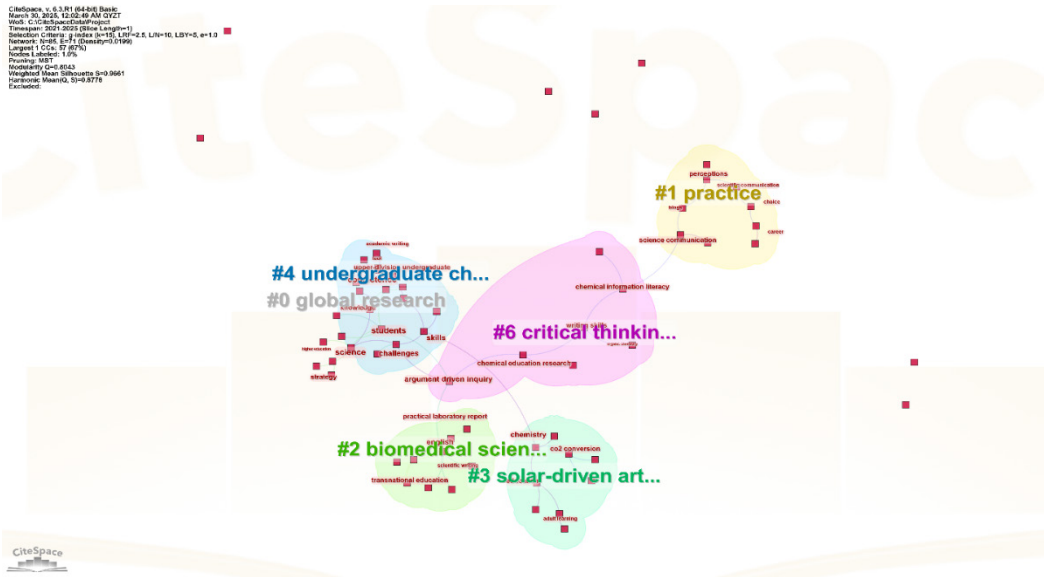

Figure 2. *Keyword network based on articles published between 2021 and 2025 (Chen et al., 2010)*

C. The intellectual structure of scientific writing and communication

To visualize the intellectual structure of the area under study, CiteSpace software was used, based on the methods of analyzing the citation and co-authorship of scientific literature indexed in the Web of Science Core Collection database for the period 2021-2025.

Despite the stated time interval, the analysis covers only publications for 2021-2024. This is due to the fact that at the time of the search (March 2025), publications for 2025 that meet the selection criteria were not fully presented in the WOSCC database. Thus, the results reflect the intellectual picture of the research area as of the end of 2024, which should be taken into account when interpreting the obtained clusters and trends.

Each time "slice" was based on the publications of the corresponding year. The network was cleaned using the Pathfinder algorithm, which reduced information noise and increased visualization clarity. The resulting map demonstrates the evolution of this field and identifies key thematic areas and research fronts.

Each node on the graph represents a cited article, and the lines between them represent cases of their joint citation. The size of the nodes corresponds to the frequency of citations, and the purple ring indicates a high degree of betweenness centrality, which indicates the importance of the publication as a bridge between different topics. The red rings indicate "citation bursts", i.e. periods of active attention to the source.

As a result of the analysis, 6 main clusters were identified, each of which represents a separate area in the field of scientific writing and communication. The clusters were labeled using the methods LLR (log likelihood ratio), LSI (latent semantic indexing) and MI (mutual information). Cluster silhouette values range from 0.883 to 1.0, which indicates a high consistency of themes within each cluster. Table 4 provides a summary of the selected clusters.

Table 4. *Main clusters of co-cited sources*

№ clusters	Size	Contour	Label (LSI)	Label (LLR)	Label (MI)	Year
1	9	0.90	L1 and L2 writing learning technologies	Argumentative structuring	Argumentative structuring	2021
2	9	0.974	Systematic review	Research-based writing learning	Courses	2022
3	8	0.982	Argumentation research	Science	Foreign language	2023
5	7	0.899	Constructive approach	Argumentation-based learning	Argumentative structuring	2022
6	7	1.00	Laboratory classes in chemistry	Chemistry laboratories for students	Teaching	2021
7	7	0.883	Digital literacy and metacognition	Metacognitive component	Metacognitive component	2024

Figure 3 shows a cluster map of co-authorship of scientific literature on the topic of developing scientific writing and communication skills. Each cluster displays interconnected publications grouped by thematic proximity. The color difference indicates the difference in research directions, and the cluster sizes reflect the amount of scientific activity in the corresponding area.

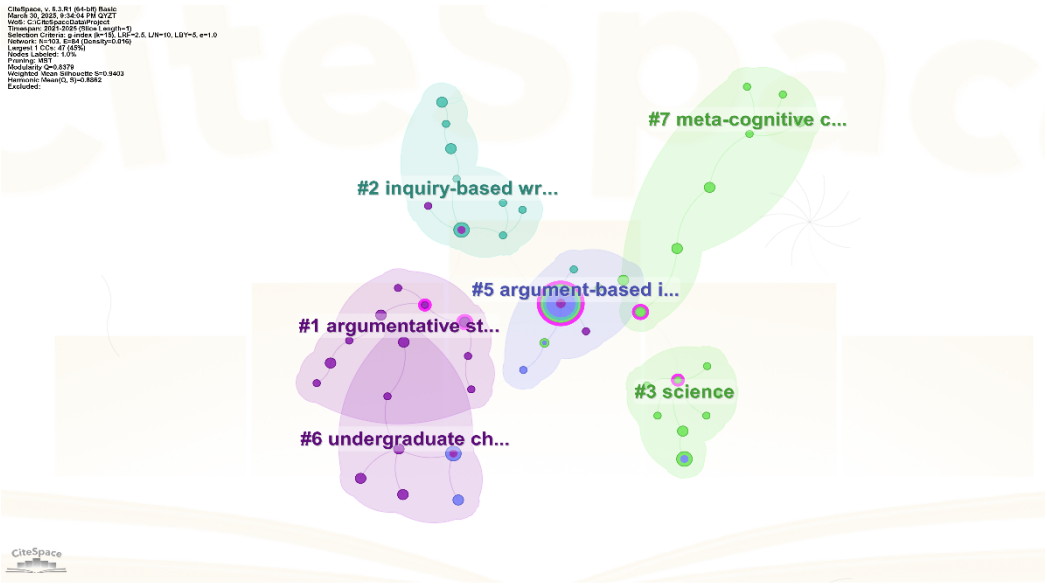

Figure 3. *Cluster map of co-authorship of scientific literature in the field of scientific writing and communication (Chen et al., 2010)*

Most of the clusters shown in Figure 4 are homogeneous, which is confirmed by the high contour values. The cluster labels were assigned based on keywords extracted from the titles of the cited articles. Cluster № 1 is devoted to argumentative structuring and reflects students' interest in metacognitive aspects and the formation of rhetorical writing skills. Cluster № 2 includes systematic reviews on the issues of teaching writing based on a research approach.

Cluster № 3 focuses on the use of scientific argumentation in writing, especially in the context of interdisciplinary and multilingual education. Cluster № 5 focuses on instructional strategies and the use of models of learning through argumentation. Clusters № 6 and № 7 are related to laboratory practice and the development of digital literacy and metacognitive abilities of students in the process of learning writing, especially in teaching foreign languages.

Thus, the identified clusters form the intellectual basis of the modern trend in the research of scientific writing and communication, allowing us to trace its evolution, main directions and development prospects.

D. Analysis of betweenness centrality

Betweenness centrality is a measure of the importance of a node in a network, reflecting the number of shortest paths passing through a given node. Nodes with high centrality play the role of connecting elements between different parts of the network and facilitate the transfer of information between clusters (Chen, 2006)

In this research using CiteSpace, eight key nodes with the highest centrality have been identified, which play a structurally important role in cluster unification. These nodes are critically necessary for linking individual clusters and forming an integrated intellectual structure in the field of scientific writing and communication development.

As shown in Figure 4, the highest value of intermediary centrality belongs to the node "argument driven inquiry" (0.38), which is part of cluster № 2, which is dedicated to teaching writing based on a research approach. This is followed by ZOHAR A (0.25) from cluster № 7, and HYLAND K (0.23), also in cluster № 2. Nodes from clusters № 3 (for example, "students" and "science") and № 4 ("scientific writing" and "practical laboratory report") are of particular interest, since they perform a connecting function between educational practice, cognitive strategies and scientific communication.

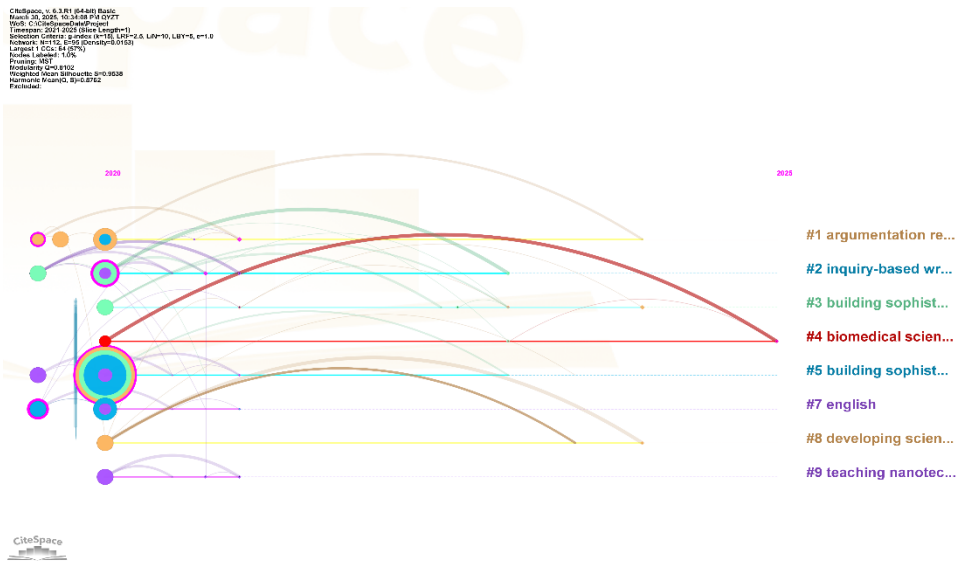

Figure 4. *Chronology of co-citation clusters (Chen et al., 2010)*

Thus, nodes with high centrality demonstrate not only quantitative significance (citation frequency), but also qualitative significance in the context of their ability to connect key research areas in the field of academic writing, argumentation, and interdisciplinary learning.

E. The results of the pedagogical experiment

As part of the pedagogical experiment, the effectiveness of the proposed model for the formation of research competencies among students studying in the field of "Forestry" was evaluated. The results of the control stage demonstrated a statistically significant increase in the level of formation of target competencies among the participants of the experimental group. In particular, more than 35% of EG students demonstrated stable skills in scientific writing, basic data analysis, and the application of field and laboratory research methods.

The total sample of the research consisted of 129 2nd-3rd year undergraduate students from two higher education institutions in East Kazakhstan:

- S. Amanzholov East Kazakhstan University, Department of Biology, Higher School of IT and Natural Sciences;
- D. Serikbayev East Kazakhstan Technical University, Higher School of Earth Sciences.

Two groups were formed:

- Experimental group (EG) - 65 students (21 boys, 44 girls) who participated in research activities;
- Control group (CG) - 64 students (23 boys, 41 girls) studying according to the standard program without additional research practice.

The pedagogical experiment was conducted in 2025 as part of the implementation of the scientific project AP25794101 to study the influence of technogenic factors and climate change on tree species growing in the industrial regions of Eastern Kazakhstan using the dendroindication method, funded by the Ministry of Science and Higher Education of the Republic of Kazakhstan under the grant program "Zhas Galym" (2025-2027). The project was coordinated by postdoctoral researcher K.B. Alipina. and it provided for the active involvement of students in the stages of field and laboratory research.

The students of the experimental group were trained in the discipline "Organization and planning of research work", which includes:

- fundamentals of scientific writing and publication compilation;
- research design and planning;
- ethical aspects of scientific activity;
- participation in field trips, core collection, analysis of annual rings.

The assessment of the formation of scientific research competencies among students was car-

ried out in three stages: ascertaining, forming and controlling, in accordance with the developed model. The diagnosis included five components previously described in the methodology section: motivational, cognitive, procedural, practical, and reflexive. At the same time, the main attention at the control stage was paid to the dynamics of the growth of indicators in the experimental group compared with the control group. The data obtained indicate significant differences in all components, especially in practical and motivational ones, which indicates the effectiveness of the implemented model.

The statistical analysis was performed manually based on the calculation of the Student's t-test and the Pearson correlation coefficient using formulas in spreadsheets. Graphs and tables built in Microsoft Excel were used to visualize the results.

The assessment of the development of scientific writing and communication skills was carried out in a number of key aspects reflecting the structure and content of the scientific text. The following components were selected as evaluation criteria:

1. Formulation of a scientific problem - the ability to clearly and reasonably present the problem under study;
2. Text structuring - logical and consistent design of scientific work sections;
3. Citation of sources - the correctness of the use of scientific sources and the observance of academic integrity;
4. Clarity and logic of presentation - consistency of argumentation and clarity of presentation of the material;
5. Use of scientific vocabulary - proficiency in terminology and style of academic writing;
6. Data interpretation - the ability to analyze the results obtained and draw informed conclusions;
7. Visualization of results - the ability to present information in the form of graphs, tables, and other visual forms;
8. Justification of conclusions - the logical conclusion of the study based on the data obtained.

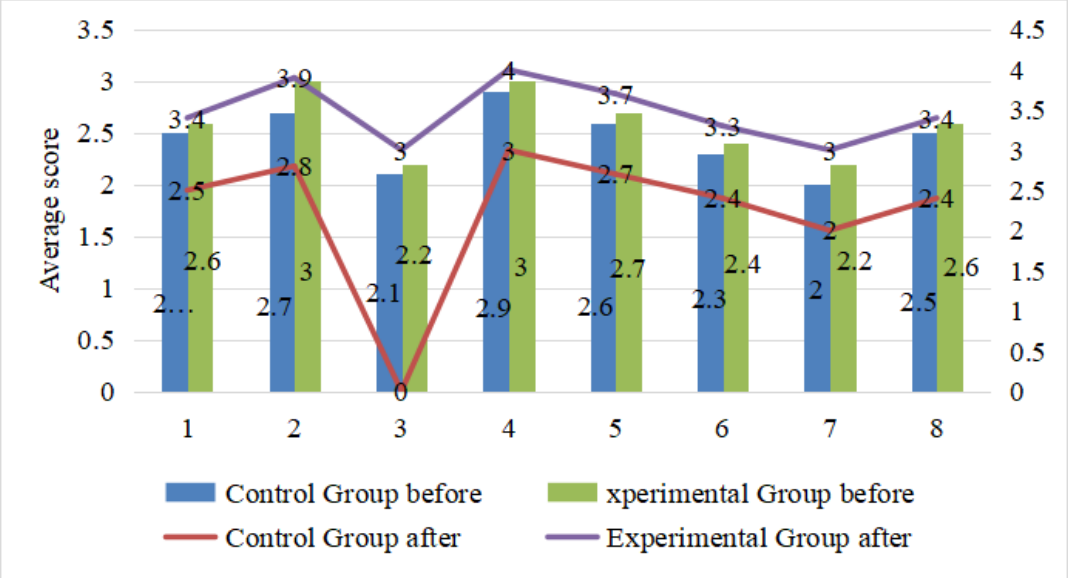

Figure 5. *Comparison of scientific writing and data analysis skills development*

In the control group, progress in all aspects was insignificant or minimal - from 0% to 4%, which indicates the absence of targeted pedagogical influence.

In the experimental group, there is a steady increase in education in all aspects from 35% to 37%, which reflects the effectiveness of the implemented model of scientific writing and communication based on research activities.

The greatest increase was recorded in terms of indicators:

- citation of sources;
- interpretation of data;
- formulation of a scientific problem.

This suggests that the integration of research activities into the learning process significantly enhances the academic and communicative competencies of students.

The effectiveness of the pedagogical experiment in each aspect of scientific writing and communication according to formulas:

$$Growth\ index = \left(\frac{X_{до} - X_{после}}{X_{до}}\right) * 100\%$$

$$Growth\ index_{avg,} = \left(\frac{3.4625 - 2.7125}{2.7125}\right) * 100\% = 27{,}65\%$$

The participants of the experimental group improved their scientific writing and communication skills by 27.65% compared to the baseline level. This indicates the high effectiveness of the applied teaching methodology, as target competencies have been strengthened by almost a third.

Net efficiency = (Growth in EG) - (Growth in CG)

Net efficiency = 0.75 - (2.475 - 2.575) = 0.75 - (-0.1) = 0.85

The net increase in results in the experimental group exceeded the control group by 0.85 points, which confirms that the positive changes were caused precisely by the experimental intervention, and not by external factors.

$$C_E = \frac{X_{EG\ after} - X_{EG\ before}}{X_{CG\ after} - X_{CG\ before}}$$

$$C_E = \frac{3.4625 - 2.7125}{2.7125 - 2.7125} = \frac{0{,}75}{-0{,}1} - 7{,}5$$

Although the coefficient turned out to be numerically negative, this is due to the fact that there was a deterioration in the results in the control group. In such cases, the negative value of E is interpreted as a strong positive effectiveness of the experiment, since the EG improved the results, and the CG, on the contrary, decreased.

The pedagogical experiment turned out to be successful and effective: the growth of scientific writing and communication skills in the experimental group was significant, the improvements were confirmed by objective calculations, and the dynamics of the control group excluded external influence.

These findings align with international research emphasizing the value of integrating scientific writing with ecological and project-based learning. For example, Septriana, Suwandi, and Sumarwati (2025) demonstrated that project-based learning combined with ecological literacy significantly improves students' scientific writing competencies.

Similarly, Hajdarpasic, Brew, and Popenici (2015) stressed that involving students in authentic research activities strengthens their academic engagement and scientific reasoning. This reinforces the observed gains in our experimental group, particularly in motivation and the formulation of scientific arguments.

Moreover, Zimmerman et al. (2006) found that visual and animated communication tools enhance public understanding of forestry practices, supporting our use of graphs and visual data presentations in student projects.

Finally, the effectiveness of applied and community-oriented forestry education was confirmed in the work of Parajuli et al. (2020), where practical engagement strategies helped participants better understand sustainable forest-based economic models. These international parallels confirm the relevance and adaptability of the proposed model in forestry education contexts.

Conclusion

This study comprehensively examined the formation of scientific writing and communication skills among forestry students through a dual methodology: (1) a scientometric analysis of international publication trends, and (2) an experimental application of a pedagogical model within two universities in Kazakhstan. The bibliometric analysis using CiteSpace software identified key thematic clusters and geographical activity areas in research on academic communication, emphasizing a gap in forestry-related contexts. Despite global engagement with scientific writing and STEM pedagogy, forestry education remains underrepresented in this domain, indicating the novelty and necessity of the current work.

To address this gap, a practice-oriented model integrating scientific writing, field research, and interdisciplinary learning was developed and piloted. The pedagogical experiment demonstrated statistically significant improvements in students' competencies, especially in the formulation of scientific problems, data interpretation, and academic writing conventions. The average improvement of 27.65% and a net effectiveness of 0.85 points confirm the success of the intervention.

These findings contribute to the growing body of literature on research-based learning and underscore the need for curriculum modernization in forestry education, especially in Kazakhstan. Future research should explore longitudinal impacts of such pedagogical approaches, as well as their integration into broader environmental education frameworks. Additionally, international collaborations could enhance the scalability and contextual adaptability of the model.

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Within the framework of this project, students participated in practice-oriented research, which created favorable conditions for the development of their scientific writing and academic communication in a real research context.

Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, K. Alipina; methodology, K. Alipina; supervision, K. Alipina; writing—original draft preparation, K. Alipina; project administration, Zh. Tergenbayeva; writing—review and editing, Zh. Tergenbayeva and Z. Dautova; validation, Zh. Kabatayeva; data curation, K. Alipina and Zh. Kabatayeva; formal analysis, Z. Bolatbekovna; visualization, Z. Bolatbekovna; investigation, N. Amangeldi; resources, N. Amangeldi; proofreading and English language editing, Z. Dautova. All authors have read and agreed to the published version of the manuscript.

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Understanding Humour in the Cognitive Resource Structure of Academically Successful Students

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Abstract: The objective of this research was to identify the specific characteristics of humour comprehension that differentiate academically successful students from their less successful counterparts, and to establish the relationship between humour comprehension and other variables within the structure of cognitive resources. A total of 325 students from various higher education institutions, representing a range of academic achievement levels, participated in the study. The research design employed a mixed-methods approach, incorporating both qualitative and quantitative methods for data processing and interpretation. The interrelationship between humour comprehension and cognitive variables was examined using factor analysis, whilst the statistical significance of group differences was assessed via the Kruskal-Wallis H test, Fisher's φ* angular transformation, and Pearson's chi-squared (χ^2) test. The total variance explained in the factor models (79.64%, 81.02%, and 95%), alongside the significance levels observed (ranging from $p \leq 0.01$ to $p \leq 0.05$), reflects the reliability and significance of the findings. Factor analysis revealed strong, positive correlations between humour comprehension and cognitive characteristics across all groups; however, the structure of these relationships differed. In high-achieving students, rapid humour comprehension was associated with a reduced speed of idea generation, while a lower reliance on factual information contributed to higher-quality humour comprehension, reflecting a high level of comic recognition. In students with average academic achievement, the factor structure showed partial integration of metacognitive, creative, and intellectual characteristics, with signs of inconsistency; a compensatory mechanism was observed for deficits in humour comprehension. In low-achieving students a discrepancy was found between the potential for humour comprehension and its underutilisation.

Keywords: *academic success, cognitive resource, humour comprehension, emotional intelligence, creativity, metacognitive characteristics.*

Introduction

The relevance of studying academic achievement in higher education stems from its pivotal role in shaping competitive professionals. Approaches to enhancing achievement through the optimisation of cognitive resources are in demand in the context of training personnel capable of addressing complex, interdisciplinary challenges, as reflected in various studies (Goegan and Daniels, 2021). The dynamic evolution of technology and the labour market requires graduates to possess not only subject-matter expertise but also metacognitive skills, the ability to self-regulate learning, and critical thinking, ensuring adaptation to changing circumstances. Consideration of students' individual cognitive profiles (for instance, through the lens of cognitive styles or abilities) enables the development of personalised learning pathways, maximising their professional potential (Privado, Pérez-Eizaguirre, Martínez-Rodríguez and Ponce-de-León, 2024). Thus, analysing academic achievement in higher education through the prism of an individual's cognitive resources not only facilitates the identification of factors determining learning effectiveness, but also the development of evidence-based strategies for improving the quality of professional training and ensuring graduate competitiveness. The investigation of cognitive factors underpinning academic achievement can be significantly enhanced and enriched by incorporating an aspect such as humour comprehension into the analysis, demonstrating a potential link with cognitive development and

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intellectual flexibility. It should be noted that the use of humour in the educational process is of considerable importance (Nurcendani and Wijaya 2022; Neff and Rucynski, 2017; Bakar and Mallan, 2023), yet its relationship with educational success is ambiguous (Cadorna, 2021). This observed ambiguity in the connection between humour and academic achievement is likely mediated by students' cognitive capabilities, or more precisely, their ability to comprehend and perceive humorous expressions (Dvoynin and Trotskaya, 2022). This research problem currently remains under-explored. In other words, the question of how a sense of humour (its comprehension and recognition) relates to cognitive resources, and whether this relationship corresponds with academic achievement, remains open.

Theoretical analysis has revealed that academic achievement is a multifaceted concept, primarily comprising objective outcomes of academic activities and a student's subjective evaluation of their accomplishments, including the attainment of individual goals (Galatskova and Petrenko, 2020; Guterman, 2021). The multi-aspectual and multi-dimensional nature of academic achievement dictates a multiplicity of evaluation criteria, which vary across a broad spectrum of indicators ranging from objective/quantitative metrics (grade point average (GPA) (Anwar, Hanurawan, Chusniyah, Setiyowati and Rehman, 2024), marks and overall grade, credit-rating systems, the correctness of test completion, and the accuracy of problem-solving (Fréchette-Simard, Plante, Duchesne, and Chaffee, 2022), response accuracy rates (Guterman, 2021) to subjective/qualitative measures: engagement in the learning process, effective time management (Lewis and Yates, 2019); persistence and resilience in achieving learning objectives (Martin et al., 2022), adaptability, and self-regulation (Anwar et al., 2024).

One of the most crucial aspects of studying academic achievement is identifying the factors and predictors that determine it. Analysis of various studies within this problem area has shown that, provisionally, these factors influencing academic success can be categorised as: personal/non-cognitive (self-efficacy (Willems, Daal, Petegem, Coertjens, and Donche, 2021), confidence, psychological capital, academic coping (Kırıkkanat and Soyer, 2018), communication skills and student engagement (Anwar et al., 2024; Chan, and Dai, 2023), motivation and self-esteem (Petukhova, 2019), anxiety (Bagandova, Ibragimova and Shamkhalova, 2018), etc.); educational (related to the assignments themselves, their complexity, strategy (Freiberg-Hoffmann, Romero-Medina, Ledesma and Fernández-Liporace, 2022). and learning model (Aydin and Demirer, 2022), etc.); social (systems of rewards and incentives for students' academic achievements (Widiarini, Supriyanto and Sunandar, 2023; Swanson and Cole, 2022) and cognitive.

The primary focus of this study is on general and specific (Dvoynin and Trotskaya, 2022) cognitive abilities. Examining research on general cognitive abilities as determinants of academic success and performance yields a wealth of empirical data concerning: the influence of general/psychometric intelligence (Bezerra, Alves, and Azoni, 2022), intellectual activity (Hülür, Gasimova, Robitzsch and Wilhelm, 2018).; fluid intelligence (including non-verbal fluid intelligence), which influences the manifestation of creativity under the mediating influence of field independence (Bouchefra et al., 2022; Giancola, Palmiero and D'Amico, 2022); intellectual flexibility, determining the effectiveness of task completion across varying levels of difficulty and future life goals Ratu, Rai, and Savitri, (2021). It has also been found that cognitive style and epistemological stance (Kholodnaya, 2024), and critical thinking correlate directly with academic self-assessment and learning outcomes (Mafarja and Zulnaidi, 2022). It is noted that a high level of development of cognitive abilities and a strong need for cognition foster intrinsic motivation and engagement in learning, as well as promoting academic achievement (Lavrijsen, Preckel, Verachtert, Vansteenkiste and Verschueren, 2021).

The influence of specific cognitive abilities (such as working memory, information processing speed, phonological awareness, the capacity to establish logical connections, and the ability to distinguish between essential and non-essential information) on academic achievement is also indisputable, finding empirical support in contemporary research (Dvoynin and Trotskaya, 2022; Postavnev, Postavneva, Dvoynin and Romanova, 2020; Tikhomirova, Malykh and Malykh, 2020).

It can be asserted that academic achievement is underpinned by an integrated intellectual-personal resource, wherein cognitive capabilities, the cognitive resource of the individual, become central. The cognitive resource serves as an individual means of integrating diverse forms of subjective experience at both the conceptual and reflective levels. It constitutes a multitude of cognitive elements that are synchronously employed by an individual during the processing of complex information and which facilitate the creation of multi-dimensional models of understanding, including the comprehension of humour at varying levels of complexity. Within this context, the capacity for humour comprehension can be regarded as an

integral component of the cognitive resource (Martin, 2007; Nomura and Maruno, 2011). It can be stated that understanding humour requires an individual to actively utilise and integrate a variety of cognitive functions: analysing information, creativity, identifying semantic relationships, formulating hypotheses, evaluating situations, and much more. Therefore, we shall examine the connection between humour comprehension and specific (most pertinent in this aspect) cognitive abilities.

It has been demonstrated that the level of cognitive development plays a crucial role in the evaluation of humour: for instance, the capacity to identify and resolve incongruities within perceived information is a key component in humour appreciation [39]. A linear relationship between humour and creativity has been identified: the higher the indices of creative thinking and creativity, the more highly developed the sense of humour in individuals (Perchtold-Stefan et al., 2020).

One of the leading predictors of humour comprehension is social intelligence in general, and emotional intelligence in particular: a high level of these determines a well-developed sense of humour, the ability to recognise it, and to react appropriately to jokes (Belesova and Nabi, 2020). It has been found that emotional intelligence positively correlates with adaptive humour styles and is a predictor of both affiliative and self-enhancing humour styles (Ogurlu, 2015). The highest significance is found in the interrelationship between humour and such variables of emotional intelligence as the utilisation and regulation of emotions (Sun, Chen and Jiang, 2017).

In certain studies, it is noted that cognitive styles (information processing styles) significantly influence preferences and the use of humour. Cognitive diversity and flexibility are associated with adaptive humour styles (Yağan and Kaya, 2024), whereas cognitive biases are associated with maladaptive humour. Humour can serve as a defensive/coping strategy, helping people to manage stress and adapt to complex, ambiguous situations (Kondrashikhina, 2021). Intuitive and reflective thinking (as defined by D. Kahneman) serves as predictors of humour perception; however, reflective thinking is more closely linked to humour-related cognition (Ventis, 2015).

Individuals with an open epistemological stance generally possess a greater capacity for humour. It can be asserted that a higher level of openness to experience leads to a greater capacity to generate a humorous perspective on a situation, with cognitive flexibility (to a greater extent) and tolerance for ambiguity (to a lesser extent) playing a key role in this process (Sun, Shen, Lin, Zhang, and Li, 2024). Openness to an epistemological stance encompasses curiosity and a desire for novel experiences, which may foster a more tolerant and humorous outlook on life (Ng, Lin, Marsh, Chan and Ramsay, 2021). Openness to an epistemological stance not only enhances cognitive flexibility and tolerance but also promotes the development of wisdom, which in turn contributes to the development of humour (Leeman, Knight and Fein 2022).

Thus, it can be concluded that humour comprehension is a complex cognitive process that extends beyond the mere recognition of the amusing. It encompasses information processing on multiple levels (levels of cognitive and emotional understanding), demanding cognitive flexibility, the capacity for abstract thought, and an understanding of social contexts, thereby providing a basis for asserting its unique role in the structure of cognitive resources. This role lies in the fact that humour comprehension functions as an integrative indicator of cognitive and emotional abilities.

It should be noted that the potential benefit of humour's influence on learning and academic success depends on a synergistic combination of the appropriate and methodologically sound use of humour by the instructor, and the student's cognitive readiness to perceive and interpret such influence. The student's ability to interpret and evaluate humour is of considerable importance and necessitates a certain level of cognitive development and background knowledge. In such instances, the utilisation of humour in education can improve the emotional state, motivation, and learning outcomes of students, while also stimulating creative and logical thinking (Gel'man, 2021). Humour related to the learning process can enhance the efficiency of cognitive processing, assisting students in better memorising and understanding learning material, and significantly improve students' behavioural accuracy (Erdoğdu and Çakıroğlu, 2021). Humour can contribute to the development of mental agility and student motivation, which favourably influences academic achievement (Oshima, 2018).

Despite a substantial body of research demonstrating the positive influence of humour on the effectiveness and success of learning, there exists data indicating the ambiguity of such influence, and refuting the assertion that the capacity to comprehend humour can be a predictor of academic success. In some instances, humour can negatively affect students and diminish their performance and cognitive perception, particularly when the humour is unrelated to academic workloads (Bolkan, Griffin and Good-

boy, 2018). It is also noted that humorous elements in learning materials, discussions, and assignments do not necessarily contribute to successful test performance (Erdoğdu and Çakıroğlu, 2021). It can be hypothesised that in all these instances, an effect of dissonance was observed between the use of humour in the educational process and the students' abilities to comprehend/perceive it, leading to a negative correlation between humour and academic achievement.

Thus, the theoretical analysis has highlighted the problematic areas of the research:

The identified problems have defined the research objective: to examine the understanding of humour as an element of the cognitive resources of students with varying degrees of academic success. It becomes theoretically justified to study the interrelationships between conceptual, metacognitive, stylistic, and creative characteristics, as well as the understanding of humour by students, as variables of cognitive resources that determine academic success. We hypothesised that a well-developed cognitive resource, incorporating the understanding and evaluation of humour, enables students not only to perceive humorous elements of learning but also to utilise them as a catalyst for more effective and profound assimilation of learning material, which ultimately contributes to academic success. Thus, the following research hypotheses were formulated:

1. Students with high academic success are characterised by well-developed abilities to evaluate and comprehend humour in various forms of witty expression, and an ease of restructuring verbal material.
2. The indicator of humour comprehension will be included in the crystallising factor of the cognitive resource structure of students with high academic success.
3. Complex and multi-dimensional interrelationships exist between the conceptual, stylistic, creative, and metacognitive characteristics of students with varying degrees of academic success, one characteristic of which is their incomplete structure.

Materials and Methods

To investigate the role of humour comprehension within the cognitive resource structure of academically successful students, we conducted an empirical study. The study design can be characterised as deductive-correlational, employing both quantitative and qualitative methods for data processing and interpretation. Specifically, we used comparative analysis (a cross-sectional approach) and statistical tests (Kruskal-Wallis H test, Fisher's φ* transformation, and Pearson's χ^2 test) to identify differences between groups. Factor analysis was employed to determine the structural relationships between humour comprehension and elements of the cognitive resource in students from different groups. The processing of diagnostic results using factor analysis was conducted via principal component analysis to identify the characteristics that significantly explain the nature of these interrelationships (IBM SPSS Statistics Subscription Trial).

The study involved students from Russian universities. The total sample size was N = 325, with participants aged between 18 and 20 years. This comprised 135 male students (41.54%) and 190 female students (58.46%). The mean age was M = 19.49, with a standard deviation of SD (σ) = 1.68, a variance of D (σ^2) = 2.83, and an effect size (Cohen's d) of d_{emp} = 0.01.

Data collection for the implementation of research methods and techniques was carried out through direct interaction with students, using structured and printed stimulus materials. All students participated in the study on a voluntary and non-compensated basis.

To determine academic success (defined as the grade point average (GPA) for the most recent semester), we used official grade reports from the universities' grading systems (serving as objective measures of academic performance), along with a questionnaire (designed to collect biographical data on the students) and students' self-reports regarding their academic performance. The inclusion of both objective indicators of academic performance and students' subjective perceptions of their own achievements allowed for a more complete and accurate representation of academic success.

To examine and assess humour comprehension in various types of witty statements, semantic, categorical, and conceptual abilities, we employed the "Humorous Phrases Test" (A.G. Shmelev and V.S. Babina). The test's stimulus material includes 100 humorous phrases, 40 of which are unambiguous and relate to specific themes (there are 10), and 60 of which are ambiguous. The unambiguous phrases, categorised by theme, assess the degree of accurate understanding of each theme. Increased motivational significance (dominance) of a theme leads respondents to more frequently associate both unambiguous

and ambiguous phrases with that theme, thereby reducing the perceived significance of other themes. Cronbach's alpha for the scales of this test was 0.80, indicating acceptable reliability and internal consistency.

Emotional intelligence was assessed using the N. Hall Test. This test comprises scales measuring emotional awareness, understanding of one's own emotions and the emotions of others, the ability to manage emotions, empathy, self-motivation, and overall emotional intelligence. Cronbach's alpha for the scales of this test was 0.81, indicating acceptable reliability and internal consistency.

The "Ideal Computer" method (M.A. Kholodnaya) was used to examine the cognitive ability of "cognitive stance." The degree of openness of the cognitive stance is determined by the predominance of objectified and categorical questions, while the degree of closedness is determined by subjectivised and factual questions. Cronbach's alpha for the scales of this method was 0.81.

To assess generalised representations of one's own cognitive process organisation techniques and cognitive strategies aimed at transforming the cognitive situation, the "Cognitive Styles of Human Individuality" (CSHI) test (V.M. Rusalov and E.V. Volkova) was used. This test allows for the identification of six pairs of cognitive style characteristics. Cronbach's alpha for the scales of this test was 0.83.

To determine the level of divergent (creative) abilities within the structure of cognitive abilities, the "Torrance Tests of Creative Thinking" (TTCT) (Subtest 2: Figure Completion) was used. This test includes six scales: fluency, originality, elaboration, resistance to premature closure, abstractness of titles, and overall creativity. Cronbach's alpha for the scales of this test was 0.80.

Results

In the first phase of the study, 325 individuals participated and were divided into three groups based on their objective academic performance (high, medium, and low). Subsequently, the students' self-assessments of their academic performance were examined within each group. The majority of students (92.30%) assessed their academic success relatively objectively, accurately reporting their average grade for the most recent semester and the current academic year, as well as their engagement in the learning process. Following the exclusion of incomplete or invalid protocols, the final sample comprised 300 individuals, and students were then differentiated based on academic success. This resulted in the identification of three groups of respondents with homogeneous (consistent across objective and subjective assessments) indicators of academic success: Group 1, high academic achievers (HAA) (85–100 points) – 58 individuals (19.03%); Group 2, medium academic achievers (MAA) (71–84 points) – 152 individuals (51%); and Group 3, low academic achievers (LAA) (≤ 70 points) – 90 individuals (29.97%). The degree of engagement, measured on a 10-point scale, was as follows for each group: high achievers – 9.43 points, medium achievers – 7.84 points, and low achievers – 7.11 points.

The analysis of students' humour comprehension regarding various types of witty statements was conducted based on three indicators: "answer congruence" (emphasising the agreement of student responses with the standard thematic classification of humorous phrases); "incongruence"; and "partial congruence" (Table 1).

Table 1. *Humour Comprehension Scores of Students with Varying Levels of Academic Success*

Groups	The proposed answers, in accordance with the standard themes of the Humorous Phrases Test, were categorised into these three groups and are presented as percentages (%):		
	congruent	incongruent	partially congruent
1. HAA	74,33	23,68	2,02
2. MAA	60,21	38,58	1,21
3. LAA	43,67	56,33	0,00

* The table uses and continues to use abbreviations for groups with high, average and low academic success: respectively – HAA, MAA, LAA

Students in Group 1 (HAA) demonstrated a significantly higher level of congruence (approximately 74.33%) with both unambiguous and ambiguous phrases when comprehending and interpreting humorous phrases, with minimal partial congruence (2.02%). This indicates their highly developed abilities in

humour comprehension and in activating semantic concepts (corresponding to specific words/phrases) as ideas, propositions, and standard thematic labels through cognitive abilities. Students in Groups 2 (MAA) – 38.58% – and 3 (LAA) – 56.33% – demonstrated a high degree of incongruence with the standard themes, reflecting their greater difficulty in recognising jokes/humorous phrases and potentially indicating an insufficient development of cognitive skills that facilitate humour interpretation. Comparative analysis of the results indicated significant differences between the groups both in the number of congruences (H_{emp} = 7.45, p ≤ 0.01) and incongruences in humour comprehension (H_{emp} = 8.21, p ≤ 0.01), reflecting the specific nature of the development of conceptual abilities in students with varying levels of academic success. Significant differences were found between the results of Group 1 compared to Group 2 (φ^*_{emp} = 2.27, p ≤ 0.05) and Group 3 (φ^*_{emp} = 4.82, p ≤ 0.01). Accordingly, the highest level of humour comprehension and ease of restructuring verbal material are characteristic of students with high academic success, supporting the first hypothesis of the study.

The observed differences in humour comprehension necessitated the identification of specific cognitive profiles characterising students with different levels of academic success (Table 2).

Table 2. *Statistical Differences in Cognitive Resource Indicators Among Students with Varying Levels of Academic Success*

Variable	Average values of indicators in groups			Нэмп.=	p≤
	1 (HAA)	2 (MAA)	3 (LAA)		
Cognitive styles of human personality					
Field dependence	12,47	12,36	12,44	6,01	0.05
Field independence	14,47	12,36	12,44	6,01	0.05
Narrow range of equivalence	15,47	16,24	19,56	10,42	0.01
Flexibility	16,54	16,39	18,89	6,49	0.03
Tolerance	18,76	18,27	21,33	7,45	0.02
Emotional intelligence indicators					
Self-motivation	9,29	8,09	13,44	8,47	0.01
Empathy	7,58	6,82	12,22	8,88	0.01
Recognition of emotions in other people	6,88	5,06	11,22	8,22	0.02
General level of emotional intelligence	6,71	3,30	7,09	11,34	0.00
Development	6,88	5,06	11,22	8,22	0.01
Indicators of cognitive position					
Objectivity	92,52	89,23	27.89	24,24	0.00
Subjectivity	7,48	10,77	72.11	17,82	0.00
Categoriality	88,85	33,56	19.53	59,81	0.00
Factuality	11,15	66,44	79.47	58,34	0.00
Cognitive position	Open	Undefined	Closed		

Analysis of the results revealed that students with HAA are distinguished by their ability to approach analysed information in an original manner, objectively identifying its key elements. This likely enables them to understand humorous situations even with some limitations in emotional intelligence (average level of development). Furthermore, these students are characterised by openness to new experiences and high (as in Groups 2 and 3) tolerance for ambiguity, providing a potential platform for cognitive development. Notably, their individual intellectual outlook is characterised by an open cognitive stance (objectification of 92.52% and categorisation of 88.85% of information, with minimal factual orientation – 11.15%), which is significantly higher in categorisation than in Group MAA (φ^*_{emp} = 8.743, p ≤ 0.01) and Group LAA (φ^*_{emp} = 10.27, p ≤ 0.01), and also significantly higher in objectification (φ^*_{emp} = 8.74, p ≤ 0.01) compared to Group LAA. This characteristic makes them flexible and receptive to new ideas and to humour. Compared to Group MAA, students in Group HAA are distinguished by (χ^2_{emp} = 825.13, χ^2_{crit} = 129.97, p ≤ 0.01) the development of symbolic, visual, and sensorimotor-emotional methods of encoding information. Students in all groups exhibited average scores in creative thinking. More highly developed field independence (χ^2_{emp}

= 121.34, χ^2_{crit} = 118.75, p ≤ 0.05), abstract conceptualisation, and reflectivity in this group (HAA) enable students to form independent yet connected interpretations, allowing them to recognise hidden aspects of information, which is important for the adequate perception of humorous allusions.

In Group MAA, emotional intelligence is below average, and a less developed ability to manage emotions was identified compared to Group HAA (χ^2_{emp} = 82.13, χ^2_{crit} = 12.97, p ≤ 0.01). They are characterised by an ambiguous cognitive stance, representing an intermediate position between the open cognitive stance (in Group HAA, φ^*_{emp} = 8.74, p ≤ 0.01) and the closed cognitive stance (in Group LAA, φ^*_{emp} = 2.1, p ≤ 0.05). It can be hypothesised that this ambiguous cognitive stance may partially function as a metacognitive factor, somewhat compensating for the less developed emotional intelligence and other cognitive characteristics, which consequently allows for a degree of adequate recognition and comprehension of humour, albeit not fully developed. Field independence, flexibility, and abstract thinking form a distinctive cognitive framework in this group. This suggests that these students likely rely on cognitive strategies in the process of processing and understanding humour. Thus, this group exhibits a degree of productive cognitive and metacognitive compensation for emotional underpinnings in humour comprehension.

In Group LAA, an average integrated score for emotional intelligence was found (with some limitations in its constituent elements) – significantly higher compared to the scores of Group MAA (φ^*_{emp} = 2.1, p ≤ 0.05), reflecting an orientation towards external social cues when solving problems. They are characterised by a concrete conceptualisation style (intolerance of ambiguity, stereotyped solutions, situational behaviour, insufficient integration of concepts, limited differentiation) (χ^2_{emp} = 49.80, χ^2_{crit} = 31.62, p ≤ 0.05). In other words, despite an average level of emotional intelligence, unproductive stylistic abilities are pronounced. Furthermore, a significant indicator for this group is a closed cognitive stance (φ^*_{emp} = 2.1, p ≤ 0.05), representing a type of cognitive attitude where students struggle to propose their own ways of making sense of information and do not always adequately perceive unusual information, including humour. However, cognitive flexibility (χ^2_{emp} = 121.34, χ^2_{crit} = 118.75, p ≤ 0.05) and tolerance of ambiguity (χ^2_{emp} = 123.37, χ^2_{crit} = 118.75, p ≤ 0.05) represent a certain potential for these students. Thus, the cognitive resource of this group reflects a contradictory pattern: the presence of productive potential in understanding information (including humour), which nevertheless remains underutilised due to the closed cognitive stance.

In summary, the obtained results (considering both significant differences and the absence thereof) reflect the varying effects and specific characteristics of the interrelationships between cognitive resource components and humour comprehension in students. Therefore, in the next phase of the study, a factor analysis was conducted within each group, employing Varimax rotation with Kaiser normalisation. This technique aims to produce a factor loading matrix in which the factors are maximally distinct from each other, facilitating straightforward interpretation.

In Group 1 (HAA), the total variance explained by the factor structure was 79.64%. The factorisation results were significant. The rotated component matrix of the factor structure consisted of 11 factors. The structure was unstable. Three variables were excluded: field dependence, concrete conceptualisation, and the “originality” scale (uniqueness/originality of ideas). In Group 2 (MAA), the total variance explained by the factor structure was 81.02%. The rotated component matrix of the factor structure consisted of 10 factors, it was incomplete and unstable. Three variables were excluded: field dependence, narrow range of equivalence, and intolerance of new experiences. In Group 3 (LAA), the total variance explained by the factor structure was 95%. The rotated component matrix of the factor structure consisted of 8 factors; the structure was complete but unstable.

We will now present a truncated version of the three most significant factors from each structure (Table 3).

Table 3. *Summarised Results of the Three Leading Factors in Groups with Varying Levels of Academic Success*

	Leading factors (1, 2, 3) of rotated component matrices									
		1 (HAA)			2 (MAA)			3 (LAA)		
№	Variable	1	2	3	1	2	3	1	2	3
1	Match with unambiguous phrases of standard topics	**0,85***	-0,11	-0,04	-0,04	**0,95***	0,06	-0,29	-0,08	-0,04
2	Mismatch with unambiguous phrases of standard topics	0,03	**0,87***	-0,03	0,01	**-0,95***	-0,06	0,29	0,08	0,04
3	Partial match with unambiguous phrases of standard topics	**0,84***	0,13	0,14	0,12	0,03	-0,01	0,34	0,25	0,01
4	Field dependence	-0.17	0,23	-0,00	-0,08	-0,38	0,02	0,28	0,45	**0,62***
5	Field independence	**0,60***	0,07	-0,18	0,74*	0,14	0,20	0,48	0,19	-0,02
6	Narrow range of equivalence	0.43	0,25	-0,06	0,43	0,02	-0,03	**0,75***	0,58	-0,03
7	Wide range of equivalence	0.34	-0,05	-0,17	0,25	0,19	-0,02	0,43	0,16	0,21
8	Flexibility	**0,67***	0,32	0,02	**0,73***	-0,07	-0,05	**0,70***	-0,03	-0,07
9	Rigidity	0,04	0,07	0,25	-0,24	-0,25	-0,42	0,05	0,00	**0,93***
10	Impulsivity	0,04	0,08	0,04	0,48	-0,21	-0,36	0,15	-0,03	-0,34
11	Reflexivity	**0,63***	0,11	0,01	-0,01	0,08	0,11	0,17	**0,92***	0,27
12	Concrete conceptualization	0,38	0,28	-0,10	0,03	-0,13	-0,21	0,21	**0,87***	-0,13
13	Abstract conceptualization	**0,78***	0,09	-0,13	**0,78***	0,17	0,23	0,13	**0,85***	0,11
14	Tolerance	**0,76***	0,22	-0,01	**0,79***	0,06	-0,03	-0,06	**0,63***	-0,16
15	Intolerance	-0,11	0,06	0,05	-0,09	0,25	-0,22	**0,54***	0,26	0,42
16	Awareness of own emotions	0,18	**0,69***	0,24	-0,28	0,12	-0,08	**0,89***	0,16	-0,12
17	Management of own emotions	0,14	-0,05	-0,15	**0,57***	-0,27	0,51	0,90*	-0,32	-0,01
18	Self-motivation	0,20	0,35	0,08	**0,68***	-0,15	0,43	**0,87***	0,33	0,00
19	Empathy	0,04	**0,90***	-0,02	0,21	-0,10	0,26	-0,02	**0,84***	-0,20
20	Recognition of emotions of other people	0,29	**0,78***	0,10	**0,52***	-0,12	0,26	0,22	**0,61***	-0,27
21	General level of emotional intelligence	**0,82***	0,26	0,06	**0,63***	-0,20	**0,50***	**0,87***	0,33	-0,16
22	Objectivity	-0,01	**0,92***	0,02	0,02	-0,11	0,14	-0,26	-0,35	**0,86***
23	Subjectivity	0,01	-0,02	-0,02	-0.02	0,11	-0,14	-0,05	0,47	0,00
24	Categoriality	-0,09	**0,93***	0,13	0,16	0,14	**0,88***	-0,31	0,04	**0,63***
25	Facticity	0,09	-0,13	**-0,93***	-0,16	-0,14	**-0.87***	-0,02	0,20	0,16
26	Fluency	-0,23	-0,14	**-0,50***	-0,37	0,17	-0,13	0,21	-0,18	-0,28
27	Originality	0,21	0,19	-0,33	0,07	**0,75***	0,01	0,09	-0,12	-0,12
28	Elaboration	0,02	-0,01	0,08	-0,13	**0,70***	0,05	0,18	-0,00	-0,60
29	Resistance to closure	0,04	0,10	-0,13	0,13	**0,50***	-0,00	-0,56	0,06	-0,28
30	Abstractness of names	**0,53***	0,10	-0,02	0,07	**0,84***	0,08	-0,59	-0,03	0,05
31	General level of creativity	0,38	0,14	-0,14	0,07	**0,92***	0,04	-0,36	-0,03	-0,28

[a] Factor extraction method: principal component analysis.
Rotation method: Varimax with Kaiser normalization.
Note: variables with the highest weight included in the crystallizing factor are highlighted in bold and an asterisk (*).

The obtained effects are clarified through an analysis of the content of the crystallising (first three, most significant) factors.

In Group 1 (HAA), the first factor (Component 1) included nine variables. The analysis revealed that humour comprehension variables have a direct interrelationship with a range of cognitive and creative characteristics: field independence, flexibility, reflectivity, abstract conceptualisation, overall emotional intelligence, tolerance for unrealistic experiences, and abstractness of titles. Accordingly, the develop-

ment of one variable will promote the development of others, suggesting the possibility of improving independent decision-making skills, cognitive flexibility, and the ability to reflect, which may influence creative perception. This result supports the second hypothesis of the study. The second factor (Component 2) includes six variables and reflects indicators of a sufficient level of awareness of one's own emotions, understanding, and managing the emotions of other people. The third factor (Component 3) included two variables with inverse relationships: factual questions and fluency of idea generation. This interrelationship indicates that the speed of humour comprehension in students may decrease due to a decrease in the speed of idea generation. At the same time, a decreased emphasis on factual information contributes to an increase in the quality of humour comprehension. Thus, indicators of humour comprehension, in interrelationship with a range of cognitive characteristics, are included in the crystallising factor of the cognitive resource structure of students with high academic success.

In Group 2 (MAA), Factor 1 (Component 1) included eight variables. Their content reflects indicators of the integration of metacognitive and emotional resources of students in the information processing. Indicators of humour comprehension (congruence with unambiguous phrases from standard themes and the inverse of incongruence with unambiguous phrases from standard themes), in interrelationship with originality, elaboration, abstractness of titles, and overall creativity, are included in the second (substantial) factor of the cognitive resource structure of students with medium academic success. The content of this factor represents a creative resource (differentiated and independent) as a potential for working with information in situations of uncertainty. Factor 3 (Component 3) included two variables: categorical and factual questions, which have an inverse relationship with each other. This inverse relationship is theoretically driven and is a sign of an ambiguous cognitive stance. The factor structure in this group is distinguished by partial integration of metacognitive, creative, and intellectual characteristics, as well as signs of contradiction (on the one hand, the ability to resist stereotyped thinking in creativity, and on the other hand – signs of an ambiguous cognitive stance).

In Group 3 (LAA), the first factor included seven variables that have a direct interrelationship. The content of the factor reflects a constellation of characteristics of emotional intelligence in interrelationship with indicators of a lack of metacognitive resource due to inversions found in the results. Factor 2 (Component 2) comprised six variables, reflecting a direct relationship between metacognitive and intellectual characteristics, even when employing information processing styles that may differ in their productivity. The third factor encompassed four variables: field dependence, rigidity, objectified and categorical questions. The interrelation of these variables points to a pronounced internal contradiction within the component structure concerning indicators of cognitive maturity. The measure of humour comprehension (agreement with unambiguous phrases on standard themes), in conjunction with objectification, categorisation, and rigidity, was only incorporated into the third (less salient) factor of the cognitive resource structure of students with low academic achievement.

Therefore, the results of the factor analysis support the third hypothesis, revealing diverse associations between cognitive, stylistic, and metacognitive characteristics within the factor structures of different student groups.

Discussions

During the empirical study, three groups of students were identified, representing varying levels (high, medium, and low) of academic achievement and corresponding self-assessments of their own academic success. It was found that students in Group 1 (High Academic Achievement - HAA) demonstrated the best performance in humour comprehension, while students in Group 2 (Medium Academic Achievement - MAA) and especially Group 3 (Low Academic Achievement - LAA) exhibited a relatively low level of humour comprehension. Substantive analysis of the cognitive resource of students with different academic achievement indicated that students in all groups require the development of stylistic and creative qualities, albeit with group-specific characteristics.

Students with high academic achievement and the highest scores in humour comprehension possess an ease in restructuring verbal gestalts and an ability to overcome existing conceptual structures and form new semantic structures. However, they exhibit insufficiently developed abilities in managing and recognising emotional states, which partially diminishes their cognitive capabilities. Provisionally, these students can be described as intellectually flexible with productive humour comprehension, against

a backdrop of reduced speed in idea generation. These results partially align with the findings of several contemporary studies (Kholodnaya, 2024; Shcherbakova, 2009; Kocak, 2018). It can be concluded that the cognitive profile identified in this group contributes to students' academic achievements.

Students with medium academic achievement and humour comprehension are characterised by the fact that the process of restructuring verbal gestalts and forming new semantic structures may present them with some difficulties. Nevertheless, they are characterised by productive metacognitive compensation for emotional misunderstanding and indications of integration with characteristics of humour comprehension. They can be defined as strategists with productive compensation of comic comprehension. This definition is supported by the research of Shcherbakova (2009), who notes that the understanding of a comic text requires the presence of an individual integrated system of emotional resource, cognitive resource of understanding, metacognitive control in the process of emotional attachment to the context and cognitive restructuring (Shcherbakova, 2009).

Students with low academic achievement and the lowest scores in humour comprehension are characterised by a pronounced inconsistency in their results. Despite possessing productive potential (the highest level of emotional intelligence among the groups), they exhibit a marked inability to utilise it (difficulties in restructuring verbal gestalts, a low capacity to overcome existing conceptual structures and form new semantic structures). Provisionally, they can be designated as individuals with an inverted resource effect in humour comprehension. These results point to an inversion of outcomes as a novel scientific finding in the context of studying cognitive humour comprehension in students.

During the identification of interrelationships between students' cognitive characteristics, factor structures were obtained that differed in content, reflecting the potential for integrating various resources (creative, metacognitive, and stylistic) when interacting with humour. It was found that cognitive and creative variables (flexibility, field independence, and abstract thinking) serve as key determinants of the ability to effectively perceive and interpret humour. This profile (identified in students with high academic achievement) facilitates not only a creative and independent perception of complex humorous contexts but also high academic achievements. These results correlate with studies emphasising the role of creativity (Perchtold-Stefan et al., 2020) and cognitive styles in humour comprehension. In particular, the ability to think analytically, recognise incongruity (corresponding to the cognitive styles of field independence and abstract thinking) allows for more effective processing of complex information contained in humorous texts and its integration into the existing knowledge system (Canestrari, Dionigi and Zuczkowski, 2014), thereby enhancing the learning process.

For students with medium academic achievement, a complex structure of cognitive variables is characteristic within the crystallising factor (field independence, flexibility of cognitive control, abstract conceptualisation, tolerance of uncertainty, emotional management, self-motivation, the ability to influence the emotional state of others, an integrative level of emotional intelligence). This suggests that a low level of abilities in managing and recognising emotions can be compensated for by cognitive strategies and self-motivation, allowing for analysis and interpretation of humour at a medium level of effectiveness. This aligns with the compensatory effort model, in which individuals with limited resources can utilise other cognitive strategies to achieve desired outcomes (Traut, Guild and Munakata, 2021).

The contradictory factor structure identified in students with low academic achievement (the presence of high potential in the realm of emotional intelligence and the capacity for cognitive adaptability, against a backdrop of structural limitations and stereotypical patterns of thinking) hinders productive humour comprehension. The existing potential for understanding information remains untapped due to a closed cognitive stance and a deficit in the skills of emotional management and adaptation to illogical experiences, which also leads to a significant reduction in academic success. These data corroborate research noting that potential cognitive resources remain unexploited due to the absence of conducive conditions for their manifestation and development (De Jonge and Huter, 2021; Tricot et al., 2020). Accordingly, the mediated development of cognitive humour comprehension within the learning process for these students may create opportunities for them to more readily assimilate complex academic tasks.

Conclusions

The results of the empirical study demonstrate a complex and multifaceted relationship between cognitive styles, emotional intelligence, and the capacity for humour comprehension in students with varying levels of academic achievement. Based on the specific results obtained across all groups, one can

posit the existence of distinct cognitive and emotional 'profiles' that determine success in humour comprehension. An open cognitive stance, well-developed information encoding styles, and abstract thinking appear to be the most effective strategies, while a closed cognitive stance and a rigid thinking style impede adequate perception of humorous stimuli. These data underscore the importance of considering individual cognitive and emotional characteristics when developing educational strategies aimed at fostering critical thinking, creativity, and the ability to understand complex social cues, including humour.

The interrelationships discovered within the factor structures reflect the potential for integrating conceptual, stylistic, creative, and metacognitive characteristics of students in relation to humour comprehension, which acquires specificity in groups of students with different academic achievement. Humour comprehension, as one of the variables of the crystallising factor of cognitive resource, contributes to the academic success of students, which aligns with the limited research on this topic (Musiichuk, 2018). At the same time, the identified crystallising factors demonstrate indications of integration not of all the productive variables studied in this regard. Thus, it can be concluded that for successful humour comprehension and the achievement of academic goals, it is necessary not only to have cognitive and emotional resources but also their productive integration, the study of which could become an important direction for further research.

Therefore, a well-developed cognitive resource, including humour comprehension and appreciation, enables the effective use of humorous elements in learning. However, the observed effects manifest with varying degrees of prominence in students with different levels of academic achievement. For students with high scores, humour acts as a catalyst for deep learning, contributing to academic success. Further research is needed to identify the specific mechanisms of humour's influence on students with medium and low scores. It is possible that these groups require methods of using humour in education adapted to their cognitive characteristics, such as a more explicit and straightforward explanation of jokes or the use of humour directly related to the material being studied. The development of such differentiated techniques will maximise the positive impact of humour on students' academic success.

The advantages of the conducted research lie in a more comprehensive and systematic approach, providing a deep and multidimensional understanding of the complex nature of academic achievement and the cognitive mechanisms that underpin it. Further research should be directed towards studying the mechanisms of interaction between cognitive and emotional factors and their integration in the process of humour comprehension, as well as developing tools for diagnosing and developing the corresponding competencies. For example, the results obtained, especially in the MAA and LAA groups, could become a basis for the development of a psycho-pedagogical training program for students. The main goal of such training could be to develop cognitive strategies in students during the processing of humorous stimuli. This could form the foundation for creating and optimising innovative approaches to the educational process and developing the cognitive potential of students.

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Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, Kibalchenko Irina, Eksakusto Tatiana; formal analysis, Kibalchenko Irina, Eksakusto Tatiana; Data curation, Kibalchenko Irina; methodology, Kibalchenko Irina; writing - original draft preparation, Eksakusto Tatiana; writing - review and editing, Eksakusto Tatiana. All authors have read and agreed to the published version of the manuscript.

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Artificial Intelligence in Art Education: Transforming Visual Arts Training

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Abstract: The rising integration of artificial intelligence into the process of creating artwork and its deployment in various professional tasks signifies a notable change in how technology is utilized across different domains. AI is rapidly becoming favoured among students to address various learning challenges. A thoughtful selection of how AI is applied in creative assignments can enhance student creativity and improve outcomes when producing diverse visual content. This article reports on an experiment aimed at generating art products using various AI applications, resulting in image creations based on verbal descriptions. The objective of the educational experiment is to motivate students to create artistic works by utilizing AI, guided by descriptive words, and improving their projects by applying them to different AI software. The research employs visual analysis and comparative analysis to assess the educational artworks produced by students, contrasting those stemming from their imagination with those generated through AI based on their descriptions. Survey Analysis of Using AI in Visual Arts Education. Findings reveal that student satisfaction levels correlate with their creativity; more creative students tend to be less satisfied with the outcomes. There are significant distinctions in the artistic and aesthetic effects of images relating to lines, shapes, and techniques. In conclusion, AI-generated images can greatly enrich the creative process by providing artists with new visual interpretations of their concepts. While AI can effectively produce new images in response to artists' creative briefs, it does not replace human creativity in the artistic process. Instead, the incorporation of AI tools serves as a complementary resource, enhancing the artistic ecosystem in the creative process.

Keywords: *visual art education, artificial Intelligence, AI-generated images.*

Introduction

The integration of artificial intelligence (AI) into professional tasks across various fields signifies a noteworthy technological advancement. In the realm of education, AI is gaining popularity among students for a wide range of tasks. A thoughtful selection of AI tools for creative activities can nurture student creativity and enhance the quality of visually striking content.

Recent studies have underscored the connection between digital technologies, artificial intelligence, and multimodal learning. These findings emphasize the potential of such tools to foster hands-on, collaborative learning environments that are enhanced by computational resources. These settings cultivate real-world problem-solving skills through collaboration, which are often challenging to replicate in traditional, individualized learning approaches (Niemi, H., Pea, R. D., and Lu, Y., 2023; Worsley, M., 2022).

United Nations Educational, Scientific and Cultural Organization, 2021 recognizes AI as a critical resource capable of addressing significant educational challenges, fostering innovation in teaching practices, and accelerating progress toward SDG 4 (Quality Education) (United Nations Educational, Scientific and Cultural Organization, 2021). Other researchers foresee AI's integration into teaching practices and core learning processes, suggesting this could profoundly enhance the quality of education by providing multimodal applications for cognitive and non-cognitive tasks (Haber, N., 2022). Additionally, integrated

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research is crucial, encouraging computer scientists to design algorithms that support multimodal learning, leveraging machine learning for personalized feedback based on student behaviour and goals (Chen, I. C., Bradford, L., and Schneider, B., 2022; Vivitsou, M., 2022).

Art education holds a vital position within higher education due to its specialized knowledge demands. Traditional teaching methods often face challenges in effectively conveying complex concepts, highlighting the necessity for AI to improve the art instruction process (Kong, F., 2020). The application of generative AI in art has been referred to as "neural media praxis," which questions conventional ideas of artistic intent and reshapes human perceptions regarding creation and interpretation (Choi, DiPaola, and Töyrylä, 2021). Neural art introduces an element of ambiguity, merging algorithmic precision with the subjective interactions between artists and technology, thereby transforming the creative process into a curated exchange. This evolution in art, described as "an art of otherness," signifies a change in the relationship between the artist and the artefact (Choi, DiPaola, and Töyrylä, 2021).

Advocates for integrating digital technologies into art education highlight the enduring relationship between art and technology, emphasizing how each has influenced the other to evolve in new ways. Over recent decades, the conversation within art education has increasingly focused on interdisciplinarity as a strategy to promote innovative teaching methods (Ryoo, A. 2014).

However, the Digital Age has prioritized advancements such as faster processing speeds and increased memory capacities, often at the expense of this symbiotic relationship between the arts.

Another important aspect of applying digital technology in art education is that, within a context where artistic principles enhance new media, it is the responsibility of art educators to incorporate artistic elements into their teaching designs thoughtfully. Relying on information and communication technology (ICT) alone, where these artistic aspects may be overlooked, would mean neglecting effective educational practices. Furthermore, portraying ICT as a universal solution ignores the fact that technology rapidly becomes outdated and is quickly replaced by newer innovations. This fast pace of obsolescence tends to have minimal impact on social and personal transformations, except perhaps to underline and exacerbate the digital divide.

These innovations aim to harness the strengths of AI while integrating human cognitive abilities, promoting a synergistic relationship between humans and computers in educational settings. This approach aligns with Douglas Engelbart's vision of "co-evolving" human-computer intelligent systems, envisioning a future where AI not only complements but also enhances human learning and interaction within educational environments (Bardini, T., 2000).

Recent advancements in AI have led to a variety of educational services, as summarized by the UNESCO Resource Guide on Artificial Intelligence (United Nations, 2021). These include:

- Natural Language Processing (NLP): This involves using AI to interpret and generate texts, which aids in semantic analysis, translations, and personalized learning experiences.
- Speech Recognition: Applies NLP to spoken words, enabling features like AI personal assistants in smartphones and games, intelligent tutoring systems, and conversational bots in learning platforms.
- Image Recognition and Processing: Uses AI for tasks like facial recognition in classroom settings, handwriting and text analysis to detect plagiarism, and image manipulation to recognize deepfakes. It also includes autonomous scoring and grading.
- Autonomous Agents: Employs AI in creating virtual avatars in games, software bots, and smart robots in virtual learning environments.
- Affect Detection: Analyzes sentiments in texts, behaviours, and facial expressions using AI.
- Data Mining Algorithms: Utilized for predictive learning diagnoses, progress forecasting, socio-emotional well-being analysis, financial predictions, and fraud detection.
- Artificial Creativity: Generates new forms of creative outputs, such as photographs, music, artwork, and stories using AI.

Over the past decade, these technologies have significantly transformed education, as highlighted by a multisector expert group convened by Digital Promise (Niemi, H., Pea, R. D., and Lu, Y. 2023). This group envisioned how AI could shape future educational practices.

In a related context, Yao, Yang, Lin, Lee, and Zhu proposed an image-to-text (I2T) framework that generates textual descriptions of visual content. This framework operates by parsing images, converting results into semantic representations, and generating human-readable text reports, utilizing vocabularies

of visual elements and stochastic grammar to define relationships between them (Yao, B. Z., Yang, X., Lin, L., Lee, M. W., and Zhu, S. C., 2010).

The development of new educational methodologies based on digital technologies and AI for multimodal learning is vital in today's educational landscape. AI-based deep learning approaches promise transformative applications across various school subjects (Korhonen, T., Lindqvist, T., Laine, J., and Hakkarainen, K., 2022). However, these methodologies remain fragmented and are often excluded from curricula. A systematic, pedagogically grounded approach is necessary to bridge the gap between rapidly advancing technologies and conservative educational systems. This divide, particularly between digital-native generations and traditional education, emphasizes the urgent need for contemporary methodologies that integrate AI and digital technologies.

While AI offers immense potential to enhance learning experiences, aligning its methodologies with established educational principles, cognitive psychology, and learning theories is critical to achieving effective outcomes. Nonetheless, as Kong (2020) points out, much of the current research focuses narrowly on specific aspects of AI in art education or its implementation stages, often neglecting the need for comprehensive planning. This oversight has limited the depth of research on AI's impact on art instruction and hindered the execution of broader strategies. (Kong, F., 2020)

Materials and Methods

As part of the experimental research, students were invited to explore the application of AI in art education through a series of structured creative tasks. The experiment aimed to assess how AI tools could support and enhance artistic development, idea generation, and technical execution. Participants engaged with AI in multiple ways, including:

- Text Generation: Utilizing AI to create written content based on their prompts, such as artist statements, project descriptions, or art critiques.
- Lesson Planning: Using AI to generate structured art lesson plans, incorporating themes, techniques, and learning objectives.
- Creative Ideation: Leveraging AI for brainstorming and conceptualizing new artistic projects, receiving AI-generated suggestions and inspirations.
- Artwork Enhancement: Applying AI-powered tools to refine and improve their artistic works, experimenting with different styles, compositions, and visual effects.
- Image Synthesis: Generating images from textual descriptions, replicating creative tasks they had previously completed manually during the semester to compare AI-assisted and independent artistic processes.

By integrating AI into their workflow, students were able to evaluate its potential as a creative assistant, analyzing its effectiveness in augmenting artistic expression, efficiency, and innovation.

In this research, we employed several approaches:

- Experimental Studies: We designed pedagogical experiments to test hypotheses, establish causal relationships, and compare groups subjected to different interventions and outcomes.
- Content Analysis: We analyzed educational materials, such as methodologies, curricula, and student work, to identify trends, biases, and patterns within the content.
- Action Research: We addressed specific teaching and learning challenges by collecting data, implementing changes, and reflecting on outcomes to enhance practices.
- Observations: We observed educational settings to gather data on teaching methods, student interactions, learning behaviours, and results.
- Survey on satisfaction with the achieved result: Actively analyzed and systematized the students' reflective feelings and evaluation and self-evaluation of the results obtained from the application of AI in their creative work, comparing the level of satisfaction with their independent creative activity.

Through this multifaceted approach, we aimed to illuminate the transformative role of AI in art education.

Results

The integration of artificial intelligence (AI) into visual arts education presents both opportunities and challenges, as demonstrated by the experimental evaluation of AI-generated content. The study assessed AI's effectiveness in various aspects of creative and pedagogical tasks, revealing its strengths in structured content generation while highlighting certain limitations in artistic originality and expressiveness.

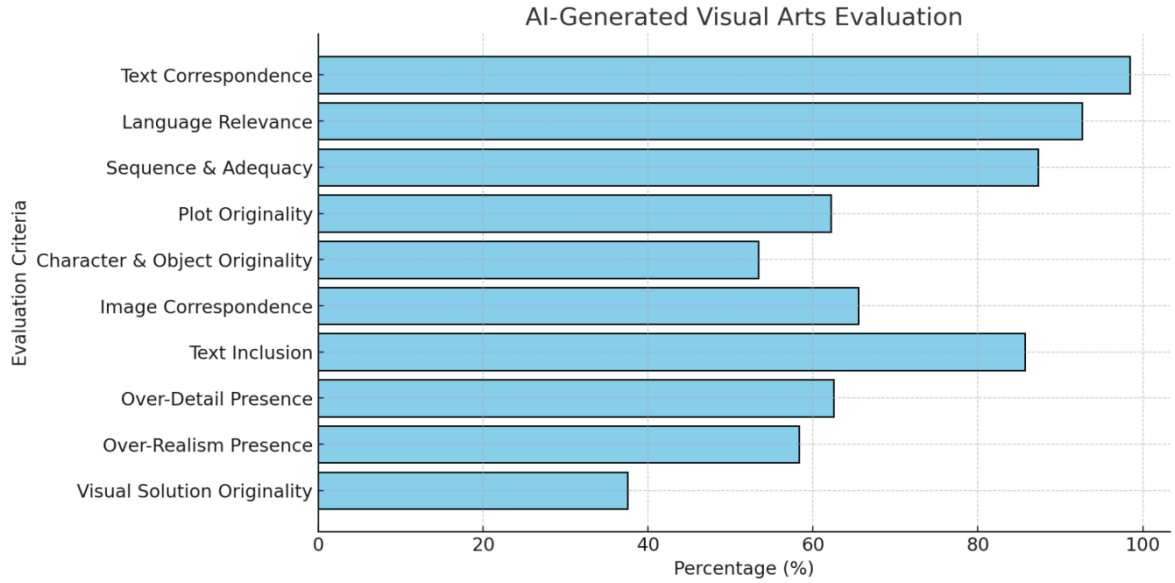

Figure 1. *AI-Generated Visual Arts Evaluation*

The findings indicate that AI performs exceptionally well in tasks that require precision and adherence to given instructions. The highest-rated criterion, correspondence of AI-generated content to the proposed prompt (98.4%), suggests that AI accurately interprets and follows textual descriptions, ensuring alignment between the input and output. Similarly, the relevance of language to the required genre (92.6%) further supports AI's capability to produce text that meets specific stylistic and contextual requirements.

Moreover, AI demonstrates considerable efficiency in structuring educational materials. The sequence and adequacy of tasks (87.3%) highlight AI's ability to organize content logically, making it a valuable tool for lesson planning and instructional design. Additionally, AI effectively incorporates requested textual elements into visual compositions, with 85.7% accuracy in text inclusion within generated images, further underscoring its potential as a multimedia support tool in arts education. (*Figure 1*)

Despite its strengths, AI-generated content presents notable limitations, particularly in fostering artistic creativity and originality. The originality of plots for visual tasks (62.2%) and originality of characters and objects (53.4%) suggest that AI-generated imagery often lacks novelty, relying on pre-existing patterns rather than truly innovative concepts. This is further reinforced by the originality of the visual solution (37.5%), which received the lowest rating, indicating that AI struggles to propose unique artistic interpretations. (*Figure 1*)

Another concern relates to AI's tendency to produce hyper-detailed and overly realistic imagery. The presence of over-detail (62.5%) and over-realism (58.3%) indicate that AI-generated visuals may sometimes appear sterile or excessively polished, potentially limiting artistic abstraction and creative interpretation. This characteristic, while beneficial for technical accuracy, may reduce the expressive potential of AI-assisted artworks. (*Figure 1*)

The survey results reveal a cautious but open attitude toward the integration of artificial intelligence (AI) in visual arts education. While many respondents acknowledge AI's potential benefits, significant concerns remain regarding its impact on creativity, authorship, and artistic quality.

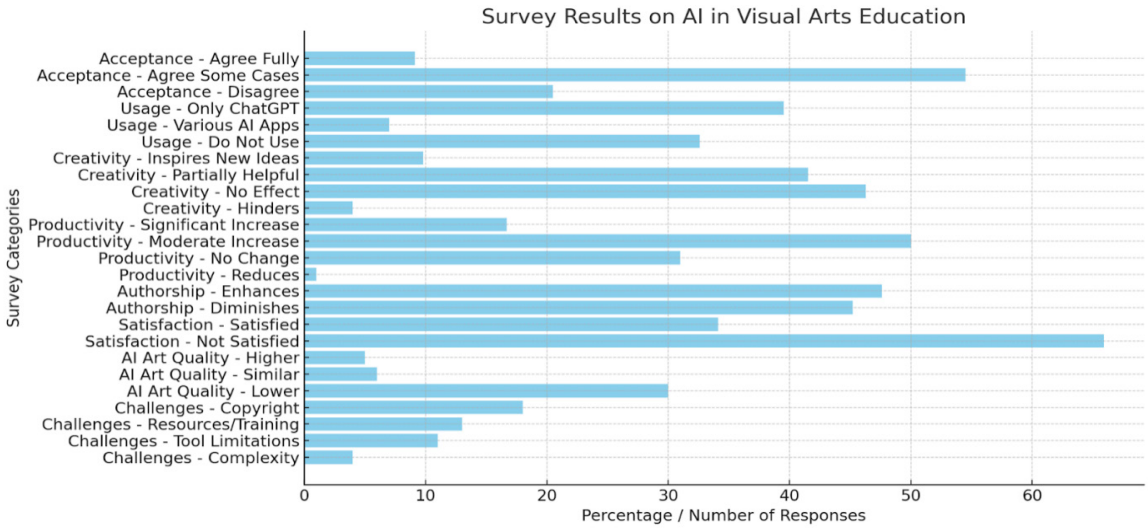

Figure 2. *Survey Results on AI in Visual Arts Education*

Some of the important results of the survey are related with:

- Acceptance and Usage of AI
  - A majority of respondents (54.5%) accept AI's role in visual arts education in select cases, while 9.1% fully support its use. However, 20.5% categorically reject it. Despite widespread awareness of AI's capabilities, its actual usage varies: 39.5% use ChatGPT exclusively, 7% experiment with different AI tools, and 32.6% do not engage with AI at all.
- AI's Role in the Creative Process
  - AI is primarily used for idea generation (14 responses), information assistance (23), and technical execution (6). It also supports tasks such as image animation, retouching, and digital drawing. However, a considerable number (18 respondents) choose not to use AI at all.
- The impact of AI on creativity is divisive:
  - Only 9.8% believe AI inspires them and generates new ideas.
  - 41.5% find AI somewhat helpful but not consistently beneficial.
  - 46.3% report no impact on their creative thinking.
  - 4% believe AI hinders their creativity.
  - AI is recognized for accelerating technical processes and enhancing productivity (66.7% report improvements), yet some fear it diminishes artistic originality and emotional depth.
- Authorship and AI-generated art
  - AI's influence on artistic authorship remains a contentious issue:
  - 47.6% feel AI enhances their sense of authorship.
  - 45.2% believe it diminishes originality, leading to a sense of co-authorship.
  - Some respondents feel AI-generated images lack individuality and artistic intent.
  - In terms of artistic quality, 65.9% express dissatisfaction with AI-generated images, citing issues such as misinterpretation of prompts, sterility, and a lack of uniqueness.
  - Only 5 respondents found AI-generated images superior to their work, while 30 rated them as lower quality.
- Challenges and Ethical Concerns
  - Several challenges hinder AI adoption in visual arts education, including:
  - Ethical concerns, particularly copyright and ownership issues (42%).
  - Lack of training and resources to effectively implement AI tools (36%).
  - Technical limitations and complexity of AI tools (26%).
  - Concerns that AI oversimplifies artistic creation, potentially stifling imagination and problem-solving skills.
  - Some artists fear that AI's accessibility might devalue traditional expertise by enabling anyone to generate art, threatening the role of trained artists. *(Figure 2)*

Discussions

The results of this study highlight the dual role of AI in art education: as a powerful assistive tool that enhances structured learning processes and as a potential constraint on artistic originality. While AI can efficiently generate structured lesson plans, provide visual references, and assist in idea development, its current capabilities suggest that it should not be viewed as a substitute for human creativity.

In the images below we show some examples of students' creations of different educational tasks as logos, posters, and illustrations, and AI-generated images of the same tasks by the prompts of the students.

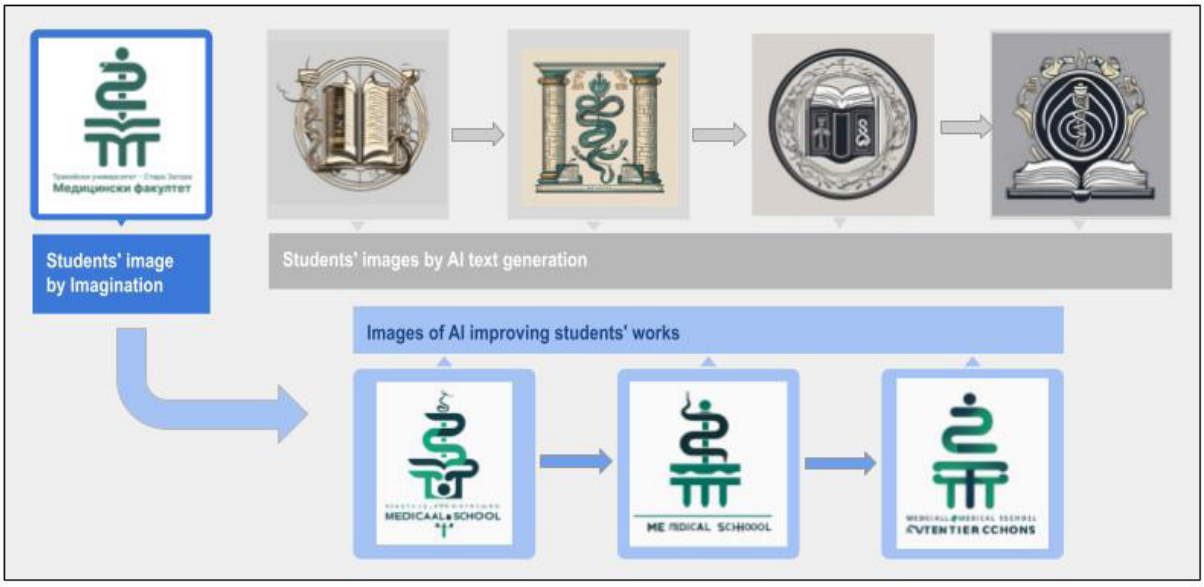

Figure 3. *Logos in 3 ways of creation*

Figure 3 shows the images generated by AI based on verbal descriptions (top row) and those created by AI as an improvement of the presented image (bottom row). In the images generated based on prompts, the excessive ornamentation and excessive detail are impressive, which deprive the proposed logos of their main meaning and purpose. In the logos proposed as variants to improve the ones created by the student, some details can be noted with a clarification of the form, but unfortunately in most cases, the semantic meaning is lost.

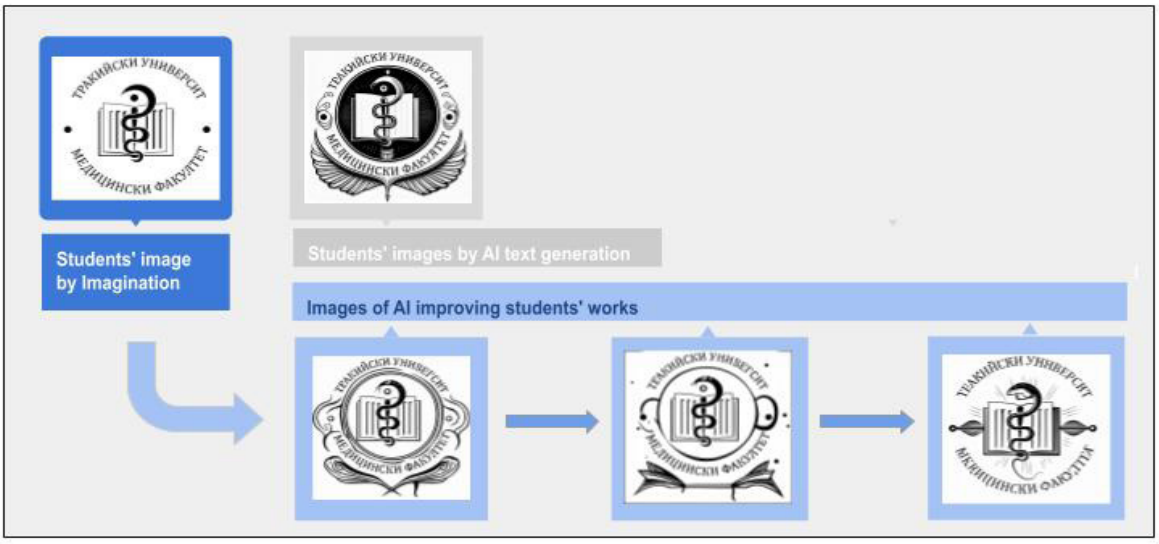

Figure 4. *Logos in 3 ways of creation*

The logos shown in Figure 4 are a demonstration of similar results to those in Figure 3 when working with AI for image generation. Complex ornamentation and unnecessary detailing in the verbally

generated image and in this case, the addition of unnecessary details and perceptually burdensome ornamentation in the images generated based on the image suggested for improvement by AI.

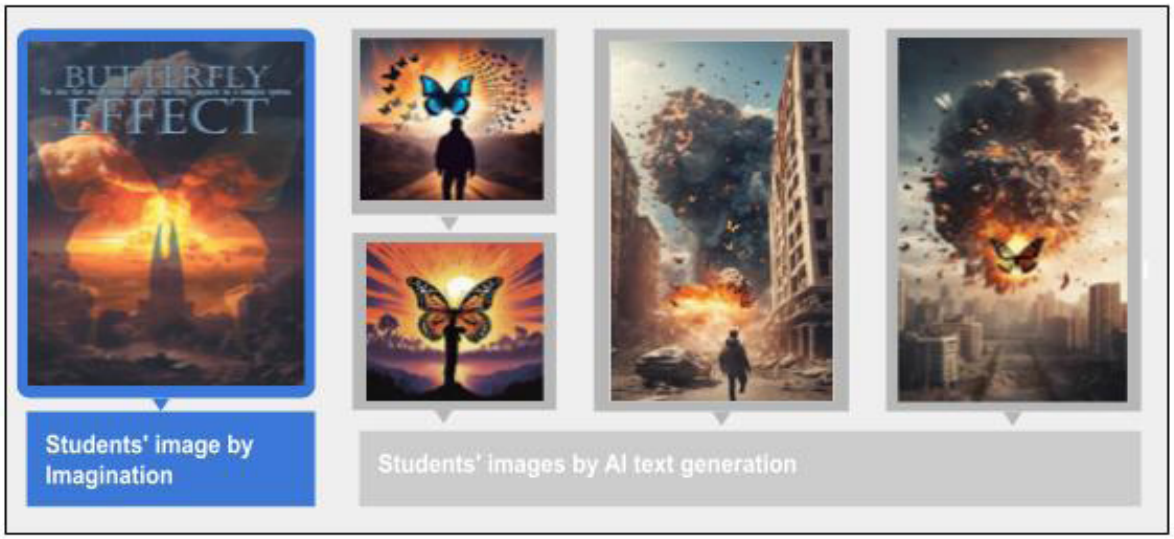

Figure 5. *Posters, created by Students and generated by AI*

Figure 5 displays posters created by a student and generated by AI based on verbal descriptions of the poster concept. The student describes their experience with AI Pixlr and the prompts used as follows: The first prompt was, “A big explosion in the background with a butterfly silhouette in the foreground.” The second prompt was, “A big explosion and a destroyed city in the background, with a butterfly flying in the foreground.”

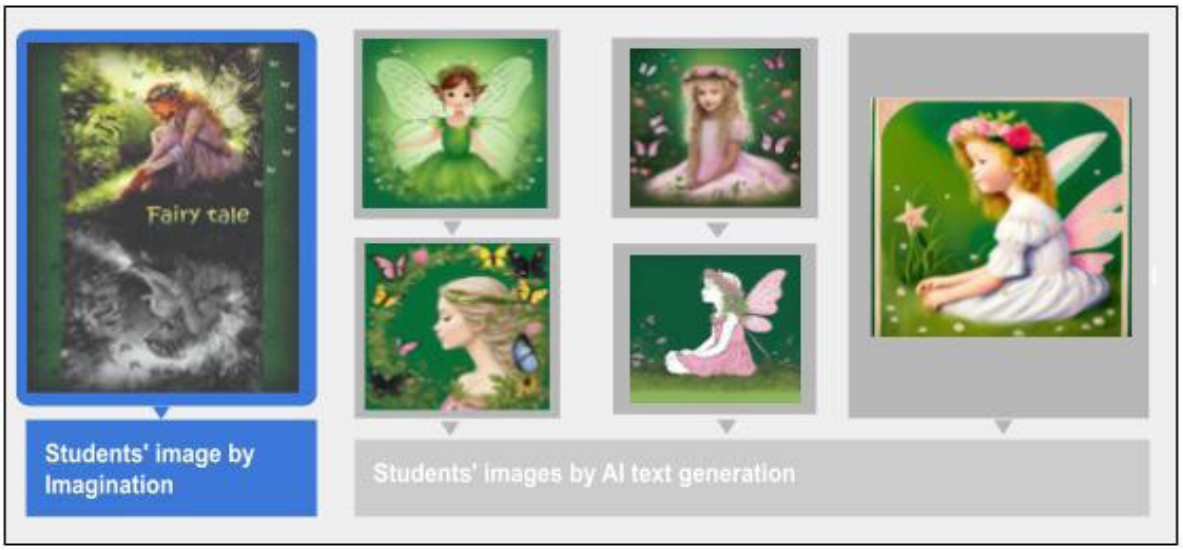

Figure 6. *Posters, created by Students and generated by AI*

Figure 6 illustrates a student’s creation of a poster through imagination, supplemented by their experience with AI FOTOR M2 for generating images based on specific prompts. The first prompt was: “Create a poster featuring a drawn girl dressed as a fairy against a green background. The fairy should be depicted realistically and in profile, looking down while seated on the grass. She should have blonde curly hair, wear a pink dress, sport a wreath on her head, and be barefoot.” The second prompt further elaborated: “Design a poster showcasing a drawn girl dressed as a fairy on a green background, maintaining a realistic style in profile, looking down, and seated on the grass with blonde curly hair, a pink dress, a wreath on her head, and barefoot. Additionally, include a black-and-white version of this image facing down beneath the first one. On the right side of the first image, add white butterflies, and on the left side of the second, include turned-around black butterflies. Between both images, place the caption ‘Fairy tale’ in green and yellow.”

In AI-generated posters, we can observe the schematization of images that leads to illogical stylization and a departure from the original intent of the poster.

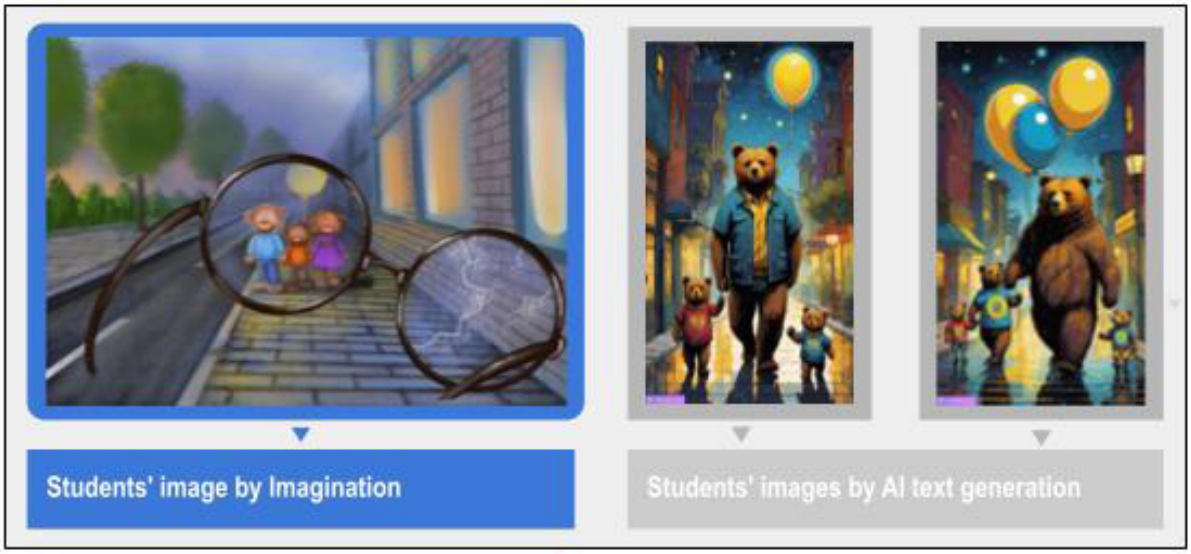

Figure 7. *Students' Illustrations by imagination and Students' images by AI text generation*

Figure 7 clearly illustrates the originality of the visual representation of the idea, which is lost in AI-generated illustrations. Additionally, there are meaning and factual discrepancies in the AI-generated illustrations.

Conclusions

In conclusion, it appears that students pursuing artistic majors exhibit resistance to utilizing AI in the creation of creative products for their academic endeavours. During their process of working and experimenting with various approaches to their creative explorations, many discover numerous opportunities to enhance their initial ideas and develop them further. Throughout their experimentation with AI, they often recognize the significance of precisely crafted verbal descriptions to achieve results that closely align with their visual expectations. However, despite having well-defined parameters for the desired image, the output generated by AI frequently presents substantial discrepancies from the specified conditions and requirements.

The findings of this research indicate a clear correlation between students' levels of creativity and their overall satisfaction with AI-generated images. More creative students tend to express lower satisfaction with these images, suggesting that individuals with higher creativity may have more rigorous standards or expectations that AI-generated images often do not meet. Additionally, the differences in satisfaction may stem from noticeable variations in the artistic and aesthetic qualities of the images, particularly concerning the use of lines, forms, and techniques.

Hyper-realistic photographic images often make AI-generated visuals less visually appealing because they lack the artistry and emotional expression characteristic of works created by real artists. Furthermore, even digital creations by live artists carry emotional depth and expressiveness that AI-generated images typically do not possess. While AI can produce images that meet specific artistic briefs, these outputs often differ subtly from the expectations of more creatively inclined individuals. AI tends to concentrate on highly detailed, hyper-realistic representations, whereas many artists prioritize abstract forms, stylization, or brevity-elements that AI struggles to replicate effectively. Consequently, the artistic impact of AI-generated visuals often falls short of the intuitive, spontaneous, and expressive qualities that human artists can achieve through traditional techniques.

The students expressed satisfaction with the experiment, primarily because it allowed them to quickly generate various visual AI solutions. They could then further develop and adapt these solutions according to their personal creative preferences and ideas.

Therefore, the integration of AI tools into the artistic process should be viewed as an enhancement rather than a replacement. AI enriches the creative landscape by providing new avenues for artistic exploration. However, it is ultimately human vision and creativity that defines the direction and emotional

impact of the artwork. By combining AI capabilities with human ingenuity, artists can expand their creative potential while still preserving the essential and deeply personal aspects of their work.

The results of the experiment and survey can help us find a way to integrate AI in art education and improve methods of application in the teaching process.

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Conflict of interests

The authors declare no conflict of interest.

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The Impact of Performance on Students' Reflective and Coping Strategies in Higher Education

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Abstract: This research aimed to track the impact of performance as a pedagogical technique on students' reflective and coping strategies. The study was conducted at the National University of Ostroh Academy (Ukraine) in the first autumn semester of 2024 (from September to December) on a sample of 120 students from such study programs as Psychology and Public Health. The type of design was a pretest-posttest experimental design (PPED), where we measured indicators both before (pretest) and after (posttest) the performance intervention. The methodological framework consisted of three approaches: the Reflective Problem-Solving Strategies (RPSS) (Savchenko and Makienko), the Coping Inventory for Stressful Situations (CISS) (Endler and Parker), and the BASIC Ph model (Lahad and Leykin). The study presented descriptive statistics, a chi-square test (x2), and Pearson's correlation analysis to show connections between reflective and coping strategies. The study stated that performance positively changes reflective strategies, transforming and adapting them to external conditions. In particular, the results showed that students most frequently employed reflective strategies such as "Criticality in Analyzing and Evaluating Information" and "Making Decisions Based on Internal Standards" to achieve a more effective and systematic analysis of problems that arise during problem-solving. The Pearson correlation analysis revealed that reflective strategies correlate most strongly with active and adaptive coping strategies, such as the Social Distraction Scale (CSSS) and Social Support (BASIC Ph), indicating the importance of social (group) interaction in the development of cognitive skills. Altogether, the avoidance coping strategies have been decreased significantly, indicating an increase in problem-solving, decision-making, and responsibility. The conclusion is that performance increases reflective strategies by directly solving problems, using external resources as emotional support and social coordination within the group. Performance can create open conditions for reflective problem-solving and deep emotional support between participants, which will further increase student achievement and learning motivation.

Keywords: *performance in higher education, performativity, reflective strategies, coping strategies, resilience, students.*

Introduction and Theoretical Framework

The modern educational environment is characterized by the fundamental revision of classical didactic approaches, considering the growing crisis in how knowledge is acquired and reproduced. In particular, the traditional or singular teaching approach assumes that the teacher is the subject, and the student is the object, where the main task is the accumulation and assimilation of knowledge (Hu, 2024, p. 215). Modern developmental psychologists and educators (Marchenko, Slipchuk and Yuzkiv, 2023; Shin, 2023; Bokolo, 2024) emphasize the fundamental inefficiency of the linear knowledge transition, underlining the importance of interaction and engagement for effective learning. In this approach, the teacher distances themselves from the student, assuming automatic reproduction of the material without emotional or physical engagement. Students need direct engagement in learning, not so much to understand but to experience knowledge performatively: "In order to address this, institutions of higher education all around the world are required to deploy engaging and innovative approaches to improve the motivation and learn-

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ing satisfaction of their students" (Bokolo, 2024, p. 1402). This fact illustrates the dual connection between cognitive processes and performative actions. On the one hand, knowledge needs its practical embodiment to be transformed into individual experience to acquire a more useful and "actionable" meaning. On the other hand, performativity enables the development of new types of knowledge and skills, often creating uncertain conditions in which students work together to seek solutions.

In our study, we define *performance* as a pedagogical approach that allows achieving educational and extracurricular results through interactive, body-oriented, and demonstrative collaboration between teacher and students. Accordingly, *performative tasks* are the results of using appropriate performative techniques (role-playing, dramatic scenarios, process drama, embodied learning, reflection, and metacognition) to create more engaging, interactive, and profound experiences. Applying performance and performativity in higher education offers an alternative to classical pedagogical methods. The classical approach suggests the teachers' role lies in a vertical hierarchy of their students (Chapman, 2021; Sahito, 2025), where the latter perceive knowledge merely as received information – a set of skills and abilities for further professional development. In contrast, a performance approach in higher education eliminates the hierarchy between educational roles, enabling a freer and often spontaneous educational process.

Some scholars connect performative learning with active learning, where the latter "has been accepted as a new learning-teaching methodology that focuses more on the participation of students than the traditional learning-teaching model" (Sahito, 2025, p. 110). Students must be perceived as active learners, and what is visible and easily observable is measured (Macfarlane and Tomlinson, 2017). Following the theories of Vygotsky and Piaget, proponents of this approach believe that active learning improves students' cognitive skills, problem-solving skills, and socialization (Bucklin et al., 2021; Sahito, 2025). Active learning involves utilizing interactive tools to achieve better cognitive outcomes. In an interactive learning environment, students function as learning resources for each other: they communicate, observe each other's work, share ideas, and make collective decisions. Macfarlane (2014) underlines this activity in the following way: "In parallel, students are now expected to demonstrate more visibly that they are 'learning' rather than simply being offered the opportunity to attend lectures and seminars. What it means to be a student, not just the product of their intellectual endeavors undertaken in private, is now observed and evaluated" (p. 339). The physical presence of students in the classroom fosters social interaction and cohesion (Baars et al., 2020), through which they exchange experiences and acquire new knowledge.

In contrast, performative learning is already a tool that enables students to transform knowledge and algorithmic (operational) skills (Carlomagno, 2021). Some of these tools and actions are conscious, which take performance beyond the group into one's individual life: "With awareness comes the ability to adjust your actions and how you interpret the actions of others" (Schechner, 2020, p. 4). This conclusion is relevant to any performance, including educational performance. Karpovets and Pasichnyk (2024) note the performative perspective "assumes two critical conditions: both the use of performative methods in the activation of one's cognitive abilities during educational activities and the achievement of the best result of cognitive activity as a performance" (p. 58). The pressure to meet grading standards and achieve high academic outcomes can either motivate students to refine their cognitive strategies or lead to maladaptive coping behaviors such as procrastination and avoidance. The task of teachers is to create an environment through their performance that promotes self-reflection and motivation for learning (Achdiyah, Latipun and Yuniardi, 2023, p. 86). Engagement in performance encourages students to grow closer to one another and to push beyond the boundaries of familiar cognitive schemes and models.

Performance focuses on the procedural aspect of education, where psychological processes such as emotional and physical engagement, student well-being and performance satisfaction are fundamental (Kulkarni et al., 2020; Nysveen et al., 2022). A distinctive feature of this educational "effectiveness" is that performance always means an activity in front of the audience or self-presentation. As Cvejić (2015) suggests, a person enacts performativity (and simultaneously becomes performative) to the extent that they can sense themselves and present their performance to others (p. 72). Hence, presentation in performance involves not only presenting the material, but also one's identity and often a group vision, which usually involves stress and anxiety (Caron et al., 2021; Grieve et al., 2021). Although some studies show that the presence of an audience might encourage a person to perform better (Zaharani and Sirehar, 2020), there is still a need to find coping strategies that students can rely on during performative learning, from the preparation stage to the final presentation.

Performative activity in higher education encompasses a wide range of actions, from engaging

with emotional intelligence (Padilla Petry et al., 2022; Bokolo, 2024) to transforming of cognitive paradigms (Nicolaides, 2022; Østern et al., 2023) through the performance of specific scenarios and practices. In a psychological context, one of the primary functions of performance in higher education is to shift the ways of thinking within academic activity (Karpovets and Pasichnyk, 2024). Students primarily assessed based on grades may focus solely on memorization and achieving high marks – essential but not central to a deep understanding of the subject. Performative activity redirects cognitive processes from surface learning to more critical and reflective comprehension of material by encouraging interaction and reflexivity (Macfarlane, 2014, p. 342), thereby fostering a holistic adjustment of thinking processes through collaborative actions. In such interaction, there are no better or worse results; every contribution is valuable and significant. Consequently, students experience less pressure than traditional classes, as the process rather than the outcome becomes the focal point of academic activity. By creating a comfortable and inclusive environment for interaction, educators aim to overcome students' fears and biases rooted in their cultural backgrounds. In other words, the teacher's "psychological goal" is to liberate students from error stress or feelings of guilt. Regarding this fact, the main elements of performance in higher education include staging, interactivity, mimesis, improvisation, creativity, and presentation (Macfarlane, 2014; Nysveen et al., 2022; Shin, 2023; Li, 2023).

The involvement of students in performance enables them to develop critical cognitive abilities and skills, which are essential for both successful learning and socialization. Researchers emphasize that one's interaction with classmates positively affects cognitive processes and changes (Anderson, 2013; Slavin, 2014; Qureshi, 2021; Arjomandi et al., 2023); thus, we assume that the more students interact with performance in their physical classrooms, the more they improve their cognitive abilities and strategies. Performance encourages not only the accumulation of knowledge about the subject but also develops personal and collective interest, creative skills, meaning-making, and problem-solving, as well as metacognitive techniques that help correct and regulate successful and unsuccessful cognitive strategies (Balashov, 2022). Finally, the interplay between reflective and coping strategies/sources in performance determines students' capacity to engage in meaningful reflection and adopt those techniques that either support or hinder their academic success (Figure 1).

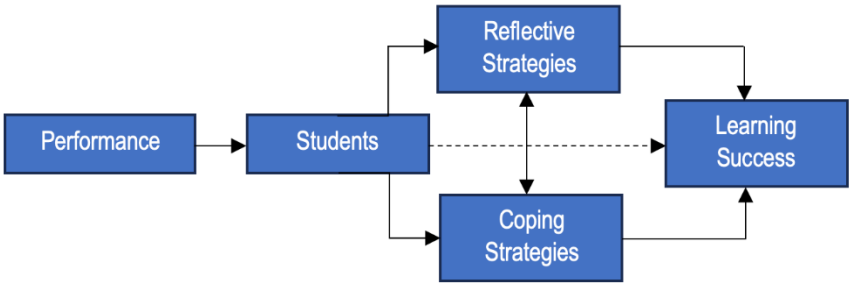

Figure 1. Conceptual diagram of the mutual influence of reflective and coping strategies on students' learning success

Higher education presents students with numerous academic, social, and psychological challenges that demand effective reflective and coping strategies (Gustems-Carnicer et al., 2019; Kalamazh et al., 2024). As Endler and Parker (1994) state, "coping strategies play a significant role in a person's adaptation to stressful life events" (p. 50); thus, learning at the university influences the development of essential strategies for long-term sustainability. Egozi-Farkash et al. (2025) state that resilience is a multi-faceted construct influenced by many factors, from individual personality traits to external support systems. We also agree with Waterhouse and Samra (2025), who define "coping as a dynamic process that is the outcome of the interaction between the individual and their environment" (p. 26). The university is such an external environment that, in addition to challenges, can also offer opportunities for resilience. In our case, we define *coping strategies* as specific psychological and behavioral techniques that help students manage stress during learning, enabling them to stay focused, motivated, and perform more effectively. All in all, understanding the relationship between academic performance and students' reflective and coping strategies within the environment is crucial for developing interventions that foster resilience, adaptability, and overall well-being in higher education settings.

We hypothesize that incorporating performance into the classroom will strengthen students' reflective strategies, encouraging them to seek coping strategies that focus on social adaptation and interaction. We assume that the more students resolve complex group tasks, the more they develop their cognitive abilities through social coping without avoiding learning challenges and problems.

Materials and Methods

We conducted an empirical study with a sample of 120 volunteer students from the Institute of Social and Humanitarian Management at the National University of Ostroh Academy (Ukraine), representing undergraduate programs such as "Psychology" (74%) and "Public Health" (26%). Participants did not receive any remuneration for their participation, and all of them belonged to the Ukrainian ethnic group. We did not consider gender differences in the sample since most students are women (M_{age} = 18,57, SD_{age} = 1,32). We collected the research data during the first autumn semester of 2024, which started in September and finished in December. The questionnaires enabled us to collect data that was available online in Google Forms, which we provided access to at the beginning and end of the courses. Participants could click on the link to the questionnaire and fill out the data while remaining anonymous.

The experiment with performance will show how students combine reflective and coping strategies to achieve performative tasks and learning success. In our study, we employed a pretest-posttest experimental design (PPED), where we measured indicators of the selected methodologies both before (pretest) and after (posttest) the performance intervention. The research design involved the use of three empirical methods: the Reflective Problem-Solving Strategies (RPSS) (Savchenko, 2016), the Coping Inventory for Stressful Situations (CISS) (Endler and Parker, 1990), and the BASIC Ph model (Lahad, 2017). The use of these models provided a robust methodological triangulation, enhancing the validity of our findings.

The RPSS approach consisted of 35 statements that allowed us to explore four reflective strategies for solving complex problems: Deep Information Processing, Criticality in Analyzing and Evaluating Information, Making Decisions Based on Internal Standards, and a Rational Approach to Problem-Solving. Each statement proposes two options that describe a specific aspect of the reflective strategy. The respondent must choose one of the given options, which is rated 1 or 0. Each reflective strategy has a defined range of points, which are divided into low, medium, and high levels. The scales were tested for consistency of their components using Cronbach's alpha (Savchenko, 2016, p. 191). As Savchenko (2016) states, cognitive strategies propose a specific strategy for obtaining, storing, and utilizing information to achieve a particular goal (p. 192). There is no conceptual or methodological distinction between reflective or cognitive strategies, as they are equally aimed at actualizing certain mental operations to resolve a difficult situation or challenge.

Simultaneously, the CISS and BASIC Ph models unpacked the specific resources that contribute to achieving the obtained cognitive results during performance. The CISS model is a designed framework that allows the definition of coping styles based on three primary dimensions: Task-Oriented Coping, Emotion-Oriented Coping, and Avoidance-Oriented Coping (Endler and Parker, 1990; Endler and Parker, 1994). The latter coping has two aspects – Distraction and Social Diversion – also present in this research. The methodology comprises 48 questions, each rated on a scale of 1 to 5 (ranging from "never" to "most often"), providing an opportunity to explore coping strategies essential for managing stress. The level of coping strategy use is determined by summing the scores according to the specified criteria.

To strengthen coping strategies, we also utilized the BASIC Ph model as an additional measure of resources for overcoming stressful situations and promoting a person's internal stability. The framework proposes six coping strategies or sources for overcoming stress: B for Belief, A for Affect, S for Social Support, I for Imagination, C for Cognitive, and Ph for Physiology (Lahad, 2017). The questionnaire presents statements through which students should rate their coping strategies for stress, ranging from "I rarely use this way to cope with a difficult situation" to "I always use this way to cope with a difficult situation" (on a scale of 0 to 6). Kalamazh et al. (2024) show a direct connection between this framework and coping strategies: "It's important to acknowledge an individual's preferred coping style in the BASIC Ph model, but all the factors can be utilized during stressful situations to strengthen or develop coping mechanisms" (p. 99). The BASIC Ph framework is also helpful because Ukrainian students studied during the war. Thus, their psycho-emotional state affects both their participation in the performance and their learning outcomes.

The collected empirical data was processed using Microsoft Excel 2024 and IBM SPSS 21. We

systematized and structured the data in Microsoft Excel 2024 before and after the experiment. In IBM SPSS 21, we tested all descriptive statistics, statistical coefficients, and dependencies.

We summarized the obtained results to analyze the changes before and after the experiment with performance (for this purpose, we standardized all results to a common level). Then, we used general descriptive statistics to understand the main characteristics of the collected data, including the mean of all the values obtained, the standard deviation, and the standard error of the mean. We used a chi-square test (x^2) to check for a statistically significant relationship between the two categorical variables ($p \leq .050$). Finally, we conducted a Pearson correlation analysis (r) on the data to determine if a pattern existed between the two continuous variables before and after the experiment ($p \leq .010$).

Results and Discussions

We generalized the collected data before and after the experiment with performance according to high, medium, and low levels in **Table 1**. The data enabled us to observe the nature of changes, correlations, and statistical errors, which we summarized in the following tables and figures.

Table 1. *The general results before and after the experiment*

Study variables	Experiment period	High level		Intermediate level		Low level	
		quantity	%	quantity	%	quantity	%
The Reflective Problem-Solving Strategies (Savchenko and Makienko)							
Deep Information Processing (DIP)	before	12	13,3	64	71,1	14	15,6
	after	17	18,9	67	74,4	6	6,7
Criticality in Analyzing and Evaluating Information	before	21	23,3	42	46,7	27	30,0
	after	38	42,2	50	55,6	2	2,2
Making Decisions Based on Internal Standards	before	9	10,0	32	35,6	49	54,5
	after	24	26,7	52	57,8	14	15,6
Rational Approach to Problem-Solving	before	18	20,0	54	60,0	18	20,0
	after	32	35,6	54	60,0	4	4,4
General Level	before	12	13,3	52	57,8	26	28,9
	after	21	23,3	60	66,7	9	10,0
The Coping Inventory for Stressful Situations (CISS) (Endler and Parker)							
Task-Oriented Coping	before	65	72,2	23	26,6	2	2,2
	after	48	53,3	38	42,2	4	4,4
Emotion-Focused Coping	before	26	28,9	59	65,6	5	5,6
	after	17	18,9	67	74,4	6	6,7
Avoidance Coping	before	22	24,4	66	73,3	2	2,2
	after	19	21,1	54	60,0	17	18,9
Distraction Scale	before	7	7,8	79	87,8	4	4,4
	after	46	51,1	34	37,8	10	11,1
Social Distraction Scale	before	49	54,4	39	43,3	2	2,2
	after	65	72,2	20	22,2	5	5,6
The BASIC Ph Model of Coping and Resiliency (Lahad and Leykin)							
Belief (B)	before	12	13,3	54	60,0	24	26,7
	after	17	18,9	65	72,2	8	8,9
Affect (A)	before	5	5,6	58	64,4	27	30,0
	after	18	20,0	70	77,8	2	2,2
Social Support (S)	before	9	10,0	47	52,2	34	37,8
	after	26	28,9	62	68,9	2	2,2
Imagination (I)	before	17	18,9	50	55,6	23	25,6
	after	18	20,0	69	76,7	3	3,3
Cognition (C)	before	48	53,3	37	41,1	5	5,6
	after	31	34,4	57	63,3	2	2,2
Physiology (Ph)	before	9	10,0	56	62,2	25	27,8
	after	19	21,1	69	76,7	2	2,2

The chi-square test (x^2) results in Figure 2 showed that the differences before and after the experiment are statistically significant. Hence, the actions during the experiment affect the improvement or deterioration of the result. There is a discrepancy between most variables because the chi-square value is more considerable. Among the reflective strategies, the strategy "Making Decisions Based on Internal Standards" has a value=31.025, Distraction Subscale has a value=49.19, and Socialization (S) has a value=38.766.

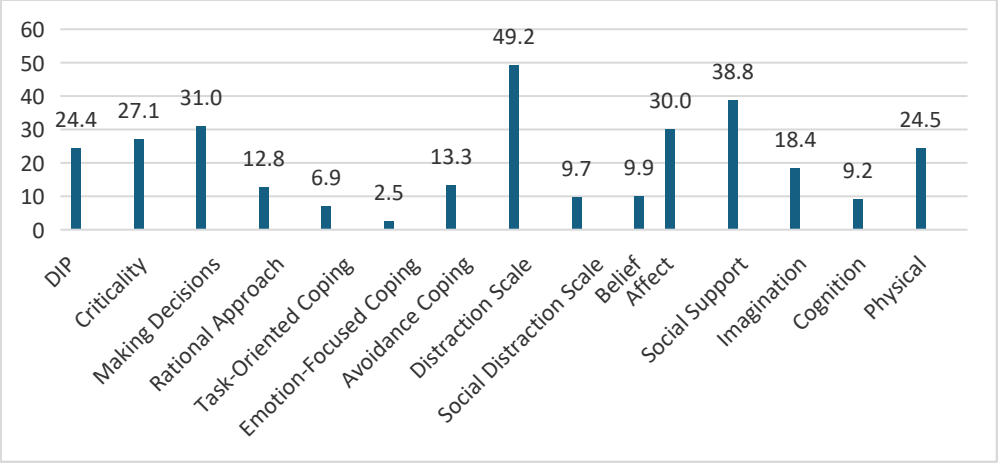

Figure 2. The chi-square test (x^2) results for the studied samples

The obtained results (Figure 3) showed variables in individual indicators, which indicates the impact of performance on students' cognitive activity. According to the given results, the strategies that changed the most on the high levels were "Making Decisions Based on Internal Standards" (from 10,0% to 26,7%), "Criticality in Analyzing and Evaluating Information" (from 23.3% to 42.2%), and "Rational Approach to Problem-Solving" (from 20,0% to 35,6%). Compared to these strategies, the strategy "Deep Information Processing (DIP)" underwent the least changes, although it also showed positive dynamics.

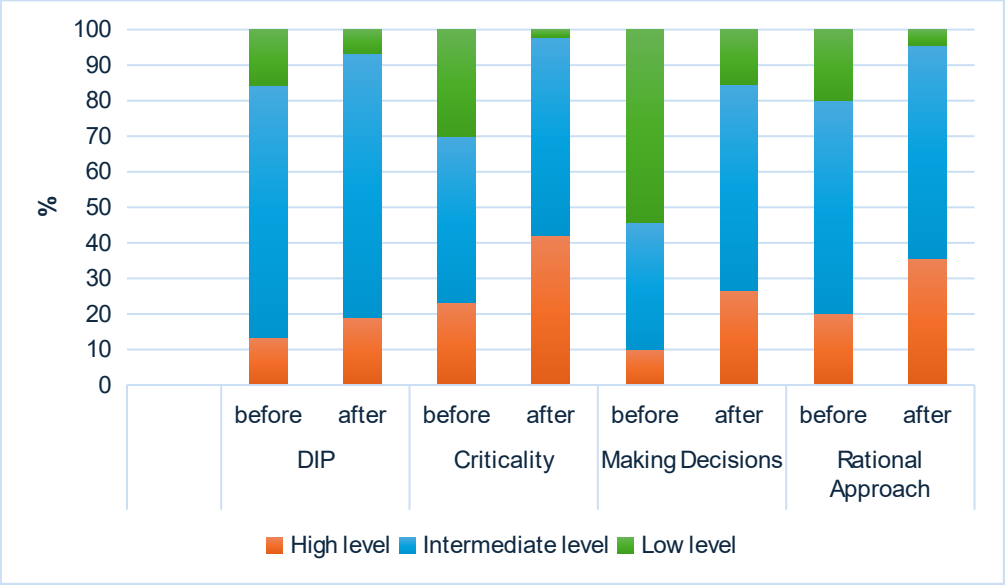

Figure 3. The general changes in the results of the Reflective Problem-Solving Strategies

The reflective strategy "Deep Information Processing (DIP)" has minor changes at all levels, indicating a moderate impact on the performance of this strategy. Since this strategy reflects "the focus of the subject's internal activity on collecting and processing information in the process of problem-solving" (Savchenko, 2016, p. 193), the higher the results of this strategy, the more subjects are "aware of their behavioral resources" (Savchenko, 2016, p. 194). The change in the overall results gives reason to believe that performance does not provide an opportunity for deep reflection and introspection because it requires "going" beyond one's experience and knowledge in search of external resources (Myroshnyk, 2020; Achdiyah, 2023). Altogether, the small changes of high and average indicators prove that for students, it is still

critical not only to solve the task but also to approach the search for a solution as "an important aspect of self-determination and self-realization" (Savchenko, 2016, p. 195).

The growth of the reflective strategy "Criticality in Analyzing and Evaluating Information" indicates a positive impact of performance on the level of students' reflectivity as an integral feature of their personality, which "ensures the correlation of their actions with the specifics of the situation, their coordination by internal and external conditions" (Savchenko, 2016, p. 196). This difference indicates that students quickly and effectively adjusted their starting points during the performance, were influenced by other participants, and corrected and improved the solution to the problem. It proves that criticality effects of thinking and behavior (Golden, 2023), and then it should "lead to practical action and real change" (Indrašiene et al., 2023, p. 2). Such a strategy develops reflectivity and helps find more accurate solutions to problems, albeit with more time and effort.

In contrast, the reflective strategy of "Making Decisions Based on Internal Standards" is focused on considering subjective assessments and judgments while "ignoring certain external requirements" (Savchenko, 2016, p. 196). The changes in this strategy after the experiment indicate that the students began to pay more attention to social support in task-solving, where the teacher's support plays a crucial role (Indrašiene et al., 2023, p. 6). The low use of this strategy (its level has fallen the most, from 54.5% to 15.6%) also contributes to an increase in the level of responsibility by increasing personal contribution to the performative solution of the task. This fact proves the assumption that there is always a division of responsibilities among the participants in performance. It is worth noting that the high use (from 10,0% to 26,7%) of this strategy reduces the ability to act independently. Therefore, it is essential for teachers also to acknowledge the individual contributions of all participants (Karpovets and Pasichnyk, 2024), who may often rely on the efforts of others (for example, more successful and proactive students).

The "Rational Approach to Problem Solving" strategy further confirms the latter trend, determining the overall level of self-regulation. As we can see, a third of students at the high level (from 20.0% to 35.6%) improved their ability to "form realistic, stable, and detailed plans" (Savchenko, 2016, p. 198) through new social connections and contacts. We assume that they could not always plan their work objectively and rationally on their own, so group work, to some extent, corrected and honed their rationality. The lack of changes at the middle level indicates that for many students, it is still critical to learn to critically overcome situations with a high level of uncertainty and control their anxiety (Kalamazh et al., 2023). The latter fact necessitates the search for coping strategies and resources to enhance students' resilience.

We also observed changes in the CISS results before and after the experiment with performance (Figure 4) to determine whether the students adjusted their coping strategies to achieve better learning and performative outcomes. The Task-Oriented Coping (from 72.2% to 53.3%) and Distraction Scale (from 7.8% to 51.1%) present a high level, the Distraction Scale (from 87.8% to 37.8%), the Social Distraction Scale (from 43.3% to 22.2%) show a medium level, and the Avoidance Coping (from 2.2% to 18.9%) demonstrates a low level of coping strategies.

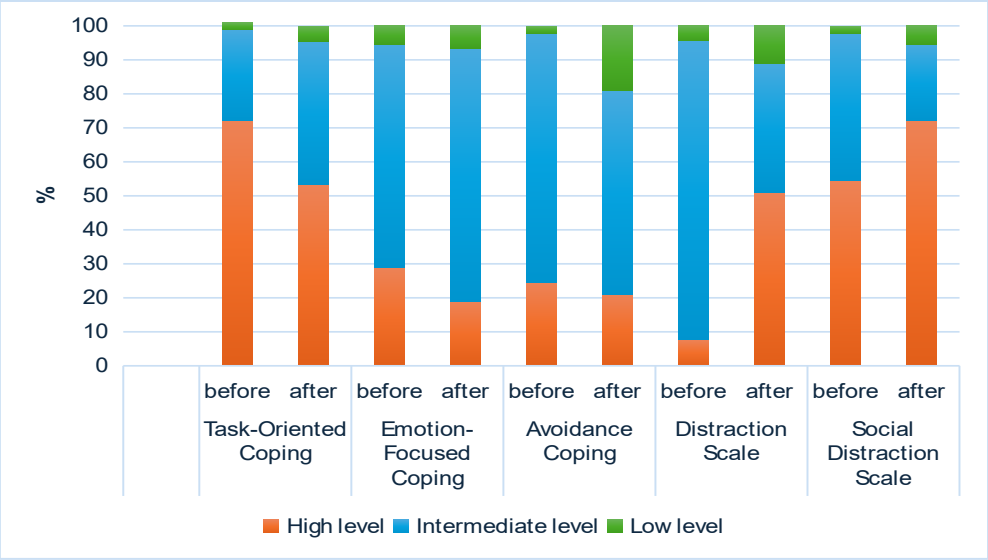

Figure 4. The general changes in the results of the CISS Strategies

The results of the BASIC Ph method (Figure 5**)** showed that Cognition (C) had changed the most at the high level (from 53.3% to 34.4%), Imagination (I) at the medium level (from 55.6% to 76.7%), and Social Support (S) at the low level (from 37.8% to 2.2%). The obtained results are the consequence of pedagogical performance, while other pedagogical techniques might have different meanings.

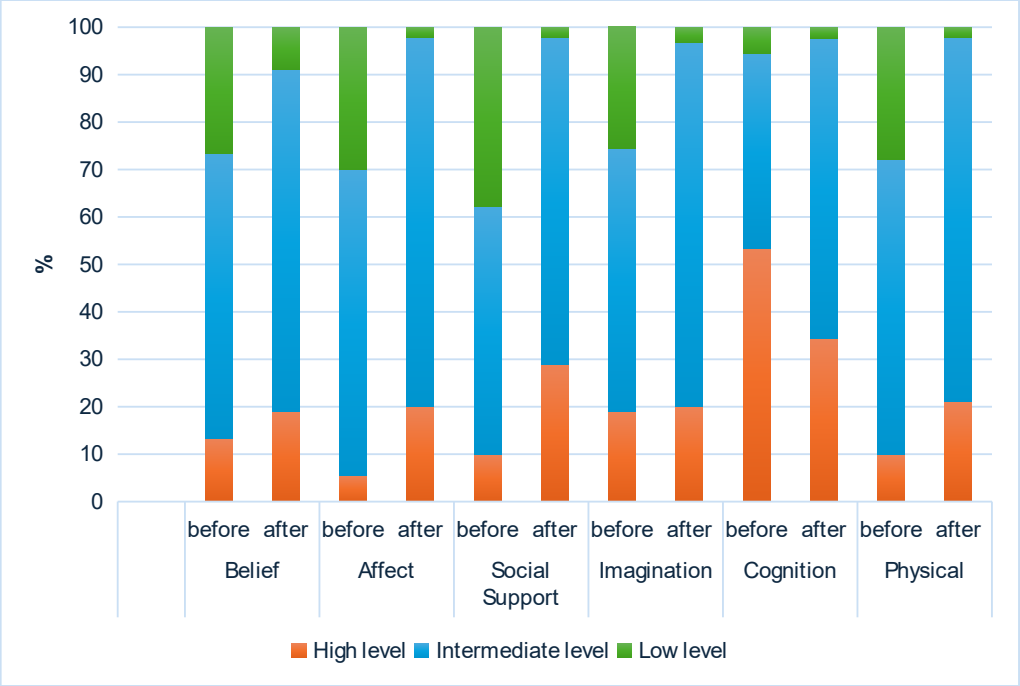

Figure 5. The general changes in the results of the BASIC Ph model

In Table 2, the Pearson correlation analysis (r) showed how the relationships between reflective strategies, coping strategies, and the BASIC Ph parameters have changed before and after the experiment, where * indicates a weak positive correlation (r = 0.20-0.39) and ** indicates a medium positive correlation (r = 0.39-0.59).

The positive correlations mainly dominate within the obtained data. However, none of the strategies showed a strong positive or negative correlation with each other (in contrast to the correlations within each strategy). Since we implemented the experiment in a short academic period (1 semester), there was not enough time to establish a deeper correlation between the data. However, even for this brief period, there is a noticeable tendency in the increase or decrease of correlations between the data, which indicates the influence of performance on students' reflective and coping strategies in their learning process.

The positive correlation between the reflective "Deep Information Processing" strategy and Task-Oriented Coping after the experiment (r = 0.428) indicates that deep reflective work encourages students to solve problems instead of avoiding them. We suggest that the reflective "Deep Information Processing" strategy involves profound processing and understanding of the material, and, therefore, students need to be critical of their cognitive experience. Accordingly, the more students "immerse" themselves in the information, the more they are critical of it and set new tasks and goals for themselves, overcoming doubts and uncertainty in such a way (Asikainen and Gijbels, 2017). From the perspective of educational psychology, this relationship highlights how deeper levels of cognitive processing contribute to more proactive, purposeful responses to academic demands (Indrašiene at al., 2023).

Table 2. *The correlation between data before and after the experiment*

Study variables	Experiment Period	The Pearson Correlation Coefficient (r)				
		Deep Information Processing	Criticality in Analyzing and Evaluating Information	Making Decisions Based on Internal Standards	Rational Approach to Problem Solving	General Level
Task-Oriented Coping	before	0,295*	0,144	-0,022	0,093	0,212
	after	0,428**	0,081	0,241*	0,362*	0,401*
Emotion-Focused Coping	before	0,019	-0,051	0,1	-0,311*	-0,083
	after	0,102	0,112	0,362*	0,092	0,286*
Avoidance Coping	before	0,352*	0,319*	-0,058	0,224*	0,296*
	after	0,042	0,149	-0,168	-0,106	0,082
Distraction Scale	before	0,202*	0,301*	-0,148	0,297*	0,252*
	after	0,052	0,074	-0,118	0,082	0,063
Social Distraction Scale	before	0,146	0,195	-0,003	0,136	0,193
	after	0,327*	0,352*	0,303*	0,286*	0,332*
Belief	before	0,048	0,126	0,065	0,036	0,107
	after	-0,037	0,142	0,016	0,112	0,03
Affect	before	0,042	0,027	-0,032	-0,149	-0,073
	after	0,144	0,413**	0,182	0,041	0,301*
Social Support	before	-0,006	0,202*	-0,082	0,052	0,104
	after	0,199	0,384*	0,359*	0,287*	0,361*
Imagination	before	-0,13	-0,033	0,089	-0,134	-0,09
	after	-0,147	-0,065	-0,043	-0,011	-0,222*
Cognition	before	0,109	0,138	0,001	0,196	0,177
	after	0,09	0,291*	0,164	0,427**	0,313*
Physical	before	0,125	-0,127	-0,032	-0,02	0,007
	after	0,177	0,158	0,297*	0,202*	0,267*

According to Table 2, the Avoidance Coping has decreased from r = 0.352 to r = 0.042, and the Distraction Scale has decreased from r = 0.202 to r = 0.052. We noticed that interactive exercises, participation in discussions, or group work help to assimilate the material more effectively, which confirms the positive effect of performance on these two strategies. Moreover, the positive correlation with the Social Distraction Scale (from r = 0.146 to r = 0.327) indicates that internal resources are insufficient to process information effectively, and therefore group cooperation is an important addition to achieving student success and emotional sustainability (Slavin, 2014; Asikaine et al., 2020). The current correlation proves that in performance, students form attachments through a sense of belonging and social connection as they jointly complete tasks and present their work publicly (Nysveen et al., 2022). Thus, students use the Social Distraction Scale to coordinate their thoughts and actions with other participants, positively affecting cognitive engagement in such a way. Yet some researchers are less optimistic about engagement in performance (Macfarlane and Tomlinson, 2017), so it is important not to idealize this approach and always consider the presence of students with different levels of motivation and engagement.

The "Criticality in Analyzing and Evaluating Information" strategy reflects the same trend, as students are less likely to avoid problems in their activities and more likely to perform learning tasks responsibly with their classmates. Before the experiment, the Avoidance Coping r = 0.319 and the Distraction Scale r = 0.301 demonstrated an average positive correlation. Altogether, the correlation with the Social Distraction Scale has increased from r = 0.195 to r = 0.352, while the relationship with Social Support (S) has changed from r = 0.202 to r = 0.384. Although this value did not increase significantly, it still demonstrated positive dynamics in seeking social support when students faced difficulties (such as a challenging task or needing to interact in a group) during performance (Alipio, 2020; Achdiyah, Latipun and Yuniardi, 2023).

Simultaneously, the most unexpected finding was the increase in positive correlation with Affect (A)

from the BASIC Ph model (from r = 0.027 to r = 0.413). For critical evaluation of information and effective task-solving with partners in performance, it is necessary to establish an emotional connection (vital for psychologists, who represented most of this sample). Emotion research in education suggests that the connection between affect and cognition is more than obvious, going beyond anxiety and stress Kalamazh et al., 2023). Zulvi and Abidin (2025) demonstrate that students engage in emotion-oriented coping strategies when adapting to stressors, achieving better learning outcomes (p. 36). We also suggest that these coping strategies are one of the adaptive ways to manage uncertain conditions in performance. Hence, such a correlation indicates both the importance of mastering stressful emotions and, at the same time, reveals a broader spectrum of affect (D'Mello and Graesser, 2012; Ruitenberg, 2015), which contributes to better interaction during learning.

The positive correlation between the strategy "Making Decisions Based on Internal Standards" and the social scales also confirms the importance of collective support and cooperation in solving tasks. This correlation suggests that individual activity does not conflict with the collective dynamics of performance, complementing it through developed internal standards for decision-making. At the same time, we have the opposite effect, when students build their internal standards and values through meaningful interaction within the social learning environment. The correlation shifts with Social Support (S) (from r = -0.082 to r = 0.359) and the Social Distraction Scale (from r = -0.003 to r = 0.303) illustrates the following tendency: the more students need to make decisions based on internal standards, the more they turn to social interaction (Indrašiene et al., 2023). In an academic environment, such students contribute to group activity not by passively conforming, but by enriching the dialogue with well-formed ideas, which strengthens social ties and mutual respect. This correlation can be interpreted through the prism of dialogical constructivism, when internal standards and guidelines are formed in context through a series of repetitive, even ritualistic actions, which is what provides performance. This practice requires emotional resources, as indicated by a moderate increase in the correlation with Emotion-Focused Coping (from r = 0.100 to r = 0.363). Also noticeable is the tendency to change the correlations with Task-Oriented Coping (from r = -0.022 to r = 0.241), which underscores the importance of combining a "systematic approach to problem-solving" (Savchenko, 2016, p. 197) with analysis, task distribution, and decision-making in performative learning.

Finally, the Pearson correlation analysis showed that there was a moderate positive relationship between the reflective strategy "Rational Approach to Problem-Solving" with Task-Oriented Coping (r = -0.093 to r = 0.362), Social Distraction Scale (r = -0.136 to r = 0.286), Social Support (S) (r = -0.052 to r = 0.286), and Cognition (C) (r = -0.196 to r = 0.427). The current correlations indicate that after the performance, students began to combine a rational approach with direct task-solving and social support (both coping strategies confirmed this). Suppose students previously avoided solutions in complex task-solving. In that case, they have now started to do so less, as indicated by the tendency towards a negative correlation with Avoidance Coping (from r = 0.224 to r = -0.106) and the Distraction Scale (from r = 0.297 to r = -0.082). We can also note a slight tendency towards a stronger correlation with Physiology (Ph) (from r = -0.020 to r = -0.202), which indicates the importance of engaging in this coping to control one's cognitive and emotional states (Achdiyah et al., 2023; Li, 2023).

The reflective strategies interacted the least with Belief (B) and Imagination (I) strategies, which proved a low or very low correlation before and after the experiment. We state that belief (B) requires personal (spiritual) and internal resources, while performance is more oriented towards external factors (Denzin, 2009; Arjomandi et al., 2023). Hence, the implementation of interactive and group tasks does not suggest this coping. Imagination (I) may be a way to avoid deep reflection (not because of weakness, but as a more emotionally safer strategy). However, as previous correlations have shown, students still solve and experience tasks more directly in performance, relying on each other's help. Altogether, the correlation with the general level of Reflective Problem-Solving Strategies increases students' social activity, utilizing cognitive, emotional, and physical capabilities to solve problems (Russell, 2017). This research supports the notion that coping strategies enable students to navigate academic pressures, and these strategies may vary, resulting in multiple approaches (Karyotaki et al., 2020). The results obtained may change with the use of other performative techniques; therefore, it is possible to conduct a longer experiment in the future to see how correlations will change.

The obtained results may be helpful for university educators who are evaluating their teaching performance and seeking optimal coping strategies. First, the use of performance allows students to develop reflexivity as an integral feature of their personality, critical perception of information, and a rational

approach to the subject. The cooperative nature of performance enhances reflexivity through joint discussion, critical thinking, and metacognition, thereby increasing learning outcomes. Secondly, performance may also strengthen social avoidance coping, which is essential for further adaptation. In other words, educators can use performative collaboration not only as a didactic strategy but also as a necessary resource for strengthening resilience to stress.

Conclusions

This study aimed to investigate the impact of performance on the use of reflective and coping strategies for academic tasks. We found that performance had a significantly positive effect on the average level of students' reflective skills, the increase of which was attributed to group interaction, collaboration, and critical reflection. We confirmed our hypothesis because students most developed strategies such as "Criticality in Analyzing and Evaluating Information" and "Making Decisions Based on Internal Standards" after the performance, which involved applying their reflective abilities to the specifics of the situation and finding social support in task-solving. The students' use of cognitive coping strategies, namely Task-Oriented Coping and Cognition (C), corresponds to the specifics of the academic environment, where students directly solve problems (tasks) that cause stress and anxiety to achieve success and improve their learning performance.

The most notable correlation was between reflective strategies and coping strategies, specifically social distraction (Endler and Parker) and Social Support (S) (Lahad and Leykin). The positive correlation indicates that the nature of performative tasks involves the formation of social connections, distributing roles and responsibilities, decision-making, and forming responsibility as a condition for developing students' reflectivity. Therefore, the Avoidance Coping and the Distraction Scale scores have decreased, indicating an increase in students' desire to solve the problem directly rather than look for ways to avoid it. Also, an essential result of this study was that the condition for establishing social connections in performance is emotional connection (Emotion-Focused Coping and Affect (A), which involves trust, empathy, and control of one's emotions. Therefore, performance creates the conditions for collective, more thorough, and precise problem-solving, as well as the emotional support that participants provide to one another.

Based on our findings, further research should focus on an in-depth examination of the interaction between reflective strategies and emotional intelligence in performance. This study aims to strengthen or refute our observations regarding the importance of the emotional component in achieving academic success. We also suggest implementing longitudinal studies to increase the time frame from one semester to a year of study. It may allow for the demonstration of more fundamental changes in the reflective activity of higher education students.

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Author Contributions

Conceptualization, M.K. and I.P.; Methodology, M.K. and I.P.; Software, O.N.; Investigation, M.K. and O.N.; Formal Analysis, V.B. and O.N.; Validation, V.B. and O.N.; Writing (original draft preparation), M.K. and O.N.; Writing (review and editing), I.P. and V.B. All authors have read and agreed to the published version of the manuscript.

Conflict of interests

The authors declare no conflict of interest.

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Multimodal Competence of Future Teachers – A Context of Understanding and Opportunities for Development in University Education

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Abstract: This article explores the formation and development of multimodal competence of preservice teachers in the context of teaching the disciplines Pedagogy of Construction and Technology Activities and Productive Activities in Technical and Technological Education in Kindergarten and in School 1st to 4th year classes. Students' multimodal competence is seen as a synergistic confluence of knowledge and skills related to different modes of communication - verbal, non-verbal, visual and digital. The focus is on the skills of selecting, combining, adapting and developing multimodal educational content, integration of communication channels and technological combination of different modalities in multimodal modes. The pilot study evaluated the feasibility of designing multimodal resources that respond to students' ages, levels of competence, learning styles, technological capabilities, and subject matter content, as well as creating learning environments that support students' cognitive, social, emotional, and personal development. The article emphasizes the need to integrate this knowledge into pedagogical practice, taking into account the ethical principles and value focuses that guide the design of multimodal environment. The results of the study show a significant improvement in students' skills in creating and adapting multimodal resources, and also highlight the importance of applying new technologies and artificial intelligence in the educational process in order to develop critical thinking, creative expression and personal growth in children and students.

Keywords: *multimodal competence, operationalization and development opportunities, multimodal technologies, multimodal resources, university teacher education.*

Introduction

In contemporary education, the multimodal competence of future teachers is essential as the educational process increasingly involves a combination of different communication modes - verbal, non-verbal, visual and digital. Children and learners perceive information in a variety of ways, and technology creates new opportunities for teaching that require teachers not only to be knowledgeable about different modalities, but also to have the skills to integrate them effectively.

In the academic literature, issues related to media and information literacy have been widely discussed in recent years, not only as a foundation for the application of digital technologies in education, but also in the context of teachers' educational needs (Makarova and Makarova, 2018; Stanišić, Leković and Stošić, 2019; Stosic, Dermendzhieva and Tomczyk, 2020; Simonović, 2021; Başaran, and Arık, 2022; Vesić, Laković and Vesić, 2023; Dašić, Ilievska Kostadinović, Vlajković and Pavlović, 2024). The authors categorically state that when we talk about raising the level of education, the most important thing is teacher education. In order to modernize the learning process, it is necessary to introduce modern media in the learning process (Novkovic Stošić and all, 2018: 1099).

In this context, an in-depth study of multimodal competence is necessary to understand how it can be incorporated into the university training of future teachers, as it is considered key to pedagogical effectiveness. This is because it enables the creation of adaptive and engaging educational resources

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tailored to the needs of diverse children and students (Georgieva, 2021). Teachers who are able to integrate different communication modes can create quality environments and designs in which educational content engages learners in a more accessible and motivating way, taking into account individual learning styles and technological capabilities. Moreover, multimodal competence helps to build critical thinking and reflexivity in future teachers, preparing them for the dynamic and digitalized environment in which they will be professionally realized.

The study of the level of development of multimodal competence is necessary not only because of technological changes, but also because of the social and ethical aspects of contemporary communication. Teachers should develop an awareness of the ways in which different modalities interact and their effects on the cognitive, social and emotional development of children and students. On the basis of such research, university education can offer targeted and systematic methodological variants for the development of the multimodal competence of students - future teachers, which will provide them with the necessary knowledge, skills and attitudes for successful professional activity and competitive advantage in an increasingly complex educational reality.

Theoretical Rationale

The theoretical propositions on multimodality as an analytic discourse represent a relatively new direction in the scientific search for the significance of this phenomenon for the understanding of communication. Conceptually, multimodality denotes the interaction between different communication modes - verbal, nonverbal, visual and auditory - which, in aggregate, shape the meaning of messages. It reveals the way in which semiotic resources combine and integrate in communicative processes, conditioning not only the transmission of information but also facilitating interpretation and understanding in different contexts. The functioning of different semiotic systems in oral, written, visual and digital communication events, as well as the unlimited possibilities of their combination, highlight multi-modality as a key mechanism of social interaction. It is the specific construct that ensures the flexibility and adaptability of communication, facilitating understanding between participants in different discursive practices. In this sense, multimodality does not simply complement communication, but significantly transforms it, expanding the boundaries of traditional communication and creating new possibilities for the expression and perception of content.

As a structurally defining element of communication, multimodality has existed since the dawn of human interactions, but its role is becoming more and more tangible with the dynamic development of information technology and the intensification of global data exchange. Although the phenomenon of multimodality has accompanied the development of civilization, it is the technological breakthroughs of the second half of the 20th century that have catalyzed scientific interest in it. The diversity of communication forms in digital and media environments makes multimodality an intersection point for various disciplinary fields that analyze its manifestations in the social, cultural, and cognitive structures of the contemporary world.

The distinction between pragmatic, compositional and hierarchical approaches to communication is becoming increasingly conventional as the boundaries between these analyses blur in multimodal discourse, where the interaction between different modes of communication plays a key role (O'Halloran, 2011). In contemporary communication, meaning is no longer formed solely through isolated structural or conceptual elements, but through their dynamic integration into a unified system that adapts to different contexts and modes of perception.

In multimodal text, the distribution of modal resources and the tensions between them form visual communication as a unified mechanism. This specificity allows in pedagogy interactions to simultaneously influence "spatial perception - the ability of an individual to detect how an object is oriented according to his or her own orientation and mental rotation - the ability of an individual to imagine both two-dimensional and three-dimensional objects and to rotate them in relation to the visual representation of the same object using only his or her mind" (Tasevska, 2023: 105). Whether perceived or created, multimodal design possesses a dynamic and multi-layered nature, for one modality may temporarily dominate but is unable to exclude the influence of others and/or ignore the contextual information they provide.

While multimodal interaction analysis focuses on the interaction between communicative elements, considering their density, integrity, and their relationship to contextual information and aesthetic organization (Scollon and Scollon, 2003; Norris, 2020), as noted in previous research, critical multimodal textual

analysis within semiotics focuses not so much on the structure of communicative resources themselves, but on their social and pragmatic role in the system of codes and meanings. This distinction is particularly relevant in the context of multi-modal competence because it emphasizes the importance of not only the formal but also the functional side of communication. Future teacher education needs to focus on understanding how, through different communication modes (verbal, visual, auditory, etc.), interactants shape the context in which they are perceived. Teachers must not only be experts at discerning different semiotic resources, but also be able to anticipate and interpret how these resources relate to the cultural, social, and individual contexts of children and students. The interaction of these elements in the environment requires teachers to be aware and flexible in order to adapt their communication according to the dynamics of the situation and the needs of the children and students. When we talk about multimodal competence, it is important to bear in mind that in social and pedagogical practice not only one or two communication channels are used.

In the multimodal approach, each resource has a unique role in expressing, specifying and making sense of meanings. Here, the "chronological determinacy of cognitive algorithms as a system of codes of the socialization process" (Dyankova, 2019: 59) is taken into account, which unequivocally affirms that "there is not and cannot be a social life if it is not lived through consciousnesses that are in relations with each other" (Tasevska, Yonkova, Boradzhieva, 2015: 8). For example, when using visual and audio-visual elements, the teacher can create a more effective and engaging educational process by integrating diverse communication channels that not only support but also enhance the understanding of the educational content. In this context, it is important for teachers to be able to manage and combine different modes, taking into account the specific needs of students and the social context of learning.

Critical multimodal analysis within semiotics also highlights how social and cultural factors influence the perception of different communication elements. That is, multimodal competence requires teachers to understand how different social groups perceive communication and how different cultures may interpret visual and verbal messages differently. This dynamic between expressive media and social contexts is crucial for successful teaching because it allows teachers to create inclusive and ethically sound educational practices that take into account students' diversity and stimulate their interest and participation in the learning process.

Previous research (Dermendzhieva and Tsankov, 2023) has focused on the formation of pedagogical competence to design multimodal educational environments that stimulate the cognitive and creative activity of preschool children. A major emphasis is placed on the need for professional reflection of the children's teacher, who must work in the context of a transgressive approach. This approach involves the integration of different forms of communication and is important for the development of skills and knowledge that equip teachers to design effective learning environments. One of the main ideas is that a child teacher's competence in designing multimodal environments is formed and developed in the process of continually cultivating new knowledge and skills. This involves expanding the teacher's cognitive and practical boundaries, which creates opportunities for better understanding and inclusion of the child in dynamic educational processes. In this context, multi-modality, as a phenomenon of communication, is perceived as an essential resource that allows a variety of interactions that activate children's cognitive and creative potential. It is theorized that when children engage in multimodal educational interactions, they not only learn social experiences but also form a transgressive attitude that influences their behavioral response. This, coupled with children's multifaceted expression, the multilayered sign language, the dynamic connectivity of information media, and dialogic communication with the child, creates a complex learning environment. This environment aims at developing the visual, informational, multicultural, media and digital experiences of preschool children, helping their holistic development in the modern world. In the context of forming a holistic learning environment in kindergarten and school, multimodality plays an essential role through authenticity, dynamism and multidimensionality. It overcomes the schematicism and linearity of thinking by activating the imagination and stimulating the creative and cognitive activity of children and students. Multimodality not only enriches social interactions, but is fundamental to the development of cognitive and affective capacities that lead to deeper self-awareness and personal growth. The possibility of integrating different communication modalities in the educational environment ensures greater student engagement and increases the effectiveness of pedagogical interactions.

Previous research by the authors (Tsankov and Dermendzhieva, 2024) examined methods for evaluating multimodal digital resources developed by students who would become child-care and school teachers. The evaluation of these resources is based on principles such as autonomy, coherence,

groundedness and authenticity, with the ability to enrich the individual sensory experience of children and students and to provoke their cognitive and personal activity being key indicators of their successful application. These criteria create conditions for building resources that can enrich pedagogical interaction by stimulating creative and non-linear thinking, both at an early age and during schooling.

The design of multimodal digital resources for the purpose of environmental composition in kindergarten and school offers the possibility of creating dynamic and engaging environments that combine cognitive, affective and sensory experiences. This combination supports children's and students' development and self-awareness, while encouraging personal expression. Research highlights the importance of appropriate education for future child teachers and teachers in different types of schools, who need to have the skills to design multimodal digital resources. This creates dynamic and effective learning environments that overcome imbalances between sociocultural and individual differences and optimise the development of children and students.

The multimodal competence of future teachers is crucial for understanding and effectively using the various communicative modes that construct meaning in the educational process. The design of multimodal content does not simply convey information, but selects and structures meaning by combining visual, verbal, and other means of expression to create an overall message. In this context, multimodal communication extends the boundaries of traditional discourse, allowing for multiple layers of meaning, personalization of ideas, and dynamic adaptation to cultural and social conditions. Understanding these processes requires a specific research approach and toolkit to support teachers in designing educational resources that integrate different communication modes for more effective learning and interaction.

Materials and Methods

Within the pilot study, the multimodal competence of the students - future teachers - is viewed as a synergistic confluence of: knowledge of different modes of communication - verbal, non-verbal, visual and digital skills: (1) to select, combine, adapt and develop multimodal educational content, (2) to integrate different communication channels, (3) to technologically combine different modalities in multimodal modes, (4) to design multimodal resources according to the subjects (age characteristics, levels of competence, learning styles), technological capabilities, subject content, expected outcomes, and cross-curricular specifics, (5) designing multimodal resources while adhering to ethical principles and value-based focuses, (6) designing multimodal environments for cognitive, social, psychological, physical, emotional, and personal development and opportunities for subject expressions; attitudes and dispositions toward: (1) mode of interaction, interpenetration and complementarity of different modalities and the dynamics and interrelationships in communication, (2) personalization of the integration of communicative modes in multimodal communication settings.

The developed and approbated technology of forming multimodal competence for students - future teachers - consists of several main stages, which cover both theoretical and practical knowledge and skills. Functionally, the implemented technology is effective in two directions:

1. Regarding the quality of academic training for the students who are future pedagogical specialists: "The integration of digital writing tools into academic programs, combined with strategies to promote student engagement, can lead to improved self-efficacy and ultimately better academic performance" (Bekturova, M., A. Zhaitapova, D. Gaipov, S. Tulepova, G. Dyankova, 2024: 616).
2. Concerning the professional-pedagogical perspective of students - future pedagogical specialists, "it is the teacher 5.0 who will have to shift education from its technological focus and saturate it with more opportunities for the development of students' socio-emotional competence, which will prove to be the key to Economy 5.0 (Mihova, 2023: 20).

Therefore, initially, students are given a basic understanding of the different modes of communication, such as verbal, non-verbal, visual and digital, focusing on their role in the educational process. This knowledge forms the basis for building competence in creating effective multimodal educational resources. Then, the focus is more on the development of skills to combine, adapt and develop multimodal educational content. Students are taught how to integrate different communication channels and technologically combine different modalities into multimodal ensembles. They are also introduced to the principles of designing multimodal resources to meet students' age, competency levels, and learning

styles, as well as to match subject content and cross-curricular specifics. Technology succeeds in preparing students to design multimodal environments that not only support children/students' cognitive and social progress, but also stimulate their emotional and personal development. It is important for students to learn how to create multimodal resources that adhere to ethical principles and value-based focuses while also strengthening relationships and interactions between different communication modalities. The goal is to develop competence for dynamic and innovative pedagogical interaction, which will support the development of children/students in a multimodal educational environment.

The technology for the formation of multimodal competence is successfully integrated into the academic disciplines "Pedagogy of construction and technology activities" and "Productive activities in technical and technological education in kindergarten and 1-4 grade", which significantly enriches the learning process and develops key skills in students – future teachers. In these courses, which are aimed at developing teachers' practical skills for working with children in the early stages of education, technology is implemented through the application of a greater knowledge of different communication modes - verbal, non-verbal, visual and digital. Thus, students master the skills of matching and adapting multimodal resources according to the age characteristics and technological capabilities of children and students.

As a result of the application of this technology, students actively learn methods of integrating different communication channels and technologies that are in sync with the pedagogical goals of the disciplines. Throughout the learning process, they design multimodal resources that foster creativity, the building of constructivist and technological skills, and the development of children's cognitive abilities. In each of these disciplines, multimodal competence is seen as the basis for creating learning environments that stimulate children's active participation and expression while meeting their specific needs and levels of competence.

Through the formation and development of multimodal competence in these disciplines, future teachers are able to develop and implement educational resources that are not only technologically innovative but also pedagogically effective. The technology for multimodal design in the disciplines "Pedagogy of Construction and Technology Activities" and "Productive Activities in Technical and Technological Training" creates dynamic educational spaces that enrich children's sensory, cognitive, and emotional experiences. In this way, students acquire the necessary skills to create integrated educational environments that not only align with pedagogical goals but also offer opportunities for both individual and collective expression. This approach fosters children's and students' creative and technological engagement, encouraging active participation and innovation in the learning process.

Results

As part of the pilot study, two groups were formed: 60 undergraduate students (full-time study) and 90 master's students (part-time study). Initially, it was examined whether the distribution of the primary test data at the diagnostic stage of the study was normal or not, in order to determine which statistical methods (parametric or non-parametric) should be used. The Shapiro-Wilk test was applied for this purpose. The statistical hypotheses tested were: H_0 – the data follow a normal distribution, and H_1 – the data do not follow a normal distribution. The empirical data were subjected to statistical analysis, the results of which are shown in the following Table No.1.

Table 1. *Distribution test results (Test of Normality)*

Group	Shapiro-Wilk		
	Shapiro-Wilk Statistic	**df** Degrees of Freedom	**Sig. (p-value)** The p-value indicating whether the data significantly deviate from a normal
Bachelor's (full-time study)	.918	60	.012
Master's (part-time study)	.876	90	.027

In the Test of Normality table, the statistical significance Sig. represents the p-value used to test the null hypothesis (H_0) that the data follow a normal distribution. For the first group of students (Bachelor's, full-time study), the p-value (Sig.) is 0.012, which is less than 0.05. This indicates a statistically significant deviation from normality, meaning that the data for bachelor's students (full-time study) do not follow a normal distribution. For the second group of students (Master's, part-time study), the p-value (Sig.) is

0.027, which is also less than 0.05. This again suggests a statistically significant deviation from normality. As a result, the null hypothesis (H_0) is rejected, confirming that the data for master's students (part-time study) are also not normally distributed.

The Shapiro-Wilk test for each study group is statistically significant, i.e. p(Sig.)<0.05, which is a reason to accept the alternative hypothesis that the data studied do not have a normal distribution and the use of non-parametric methods of analysis is justified.

The established differences in the criteria "knowledge" and "skills" in the final study in the groups after the application of the technological variant based on the constructivist and situational approach to the development of multimodal competence of students in the conditions of constructivist educational environment are presented in Table 2.

The statistical interpretation of the data in terms of the degree of formation and development of multimodal competence based on the transgressive synergetic model of competence development and operationalized technological variant in the subject field of the academic disciplines "Pedagogy of construction and technology activities" and "Productive activities in technical and technological training in kindergarten and grades 1-4" is presented summarized and commented indicatively in view of the objectives of the specific empirical study. In the context of the pilot study, the focus is on the degree of formation of skills as basic constructs of multimodal competence, as well as the possibility of their development through the applied technological option.

When comparing the differences in the groups (B.Sc. and M.Sc.) in terms of K_x, a certain difference in favour of the M.Sc. students was found.

When comparing the results at the beginning and at the end of the study, Wilcoxon test (Wicoxon) was again used to compare two correlated (related) samples (groups), and the decision was based on the significance level (α), which corresponds to the empirical value of the criterion.

Table 2. *Average coefficients - degree of development by criteria*

Criterion	Average Coefficient – Development Level (K_x) Bachelor's			Average Coefficient – Development Level (K_x) Master's		
	Initial Study	Final Study	Difference (development level)	Initial Study	Final Study	Difference (development level)
Knowledge of different communication modes	0,24	0,52	0,28	0,29	0,63	0,34
Selection, combination, adaptation, and development of multimodal educational content	0,31	0,64	0,33	0,35	0,72	0,37
Integration of different communication channels	0,22	0,58	0,36	0,28	0,65	0,37
Technological combination of different modalities in multimodal modes	0,30	0,52	0,22	0,45	0,85	0,40
Design of multimodal resources according to:	0,21	0,53	0,32	0,32	0,69	0,37
Subjects	0,20	0,45	0,25	0,22	0,52	0,30
Technological possibilities	0,18	0,40	0,22	0,42	0,86	0,44
Subject content	0,30	0,70	0,40	0,35	0,80	0,45
Expected results	0,25	0,75	0,50	0,40	0,85	0,45
Interdisciplinary specifics	0,12	0,35	0,23	0,20	0,42	0,22
Design of multimodal resources while adhering to ethical principles and value focuses	0,36	0,66	0,30	0,42	0,80	0,38
Design of multimodal environments	0,18	0,68	0,50	0,22	0,86	0,64

The results of the application of the Wilcoxon test (Wicoxon) show the associated significance level, given in the order Asymp. Sig. (2-tailed), with respect to the B.Sc. p=0.045<0.05 and with respect

to the M.Sc. p=0.017<0.05, in both cases it is the basis for the conclusion that the difference between the two scores at the beginning and end of the application of the research program, i.e. The difference between the results at the beginning and the end of the study is statistically significant, which is the basis for accepting the alternative hypothesis, according to which the differences observed in the empirical data are the result of regular factors, i.e. the outcome of the applied technological option for the development of multimodal competence of students - future teachers.

Discussions

The results of the statistical interpretation of the data show clear evidence of the effectiveness of the applied technology for the formation and development of students' multimodal competence in the context of the definition of this competence as a synergistic set of knowledge and skills. In the study, the focus is on the acquisition of different modes of communication - verbal, non-verbal, visual and digital, and the possibility of integrating and combining these communication channels in multimodal modes. Evidence of the effectiveness of the approach is obtained through the significant advances in students' skills in selecting, adapting, and developing multimodal educational content, as well as in the technological combination of different modalities in view of the specific needs of learners and the conditions of the educational environment.

Essential to the development of multimodal competence is not only the ability to combine different communication channels, but also to design multimodal resources in accordance with children's age characteristics, technological capabilities and the specifics of the learning content. This includes expanding the competence of preservice teachers to design instructional resources to meet different learning styles and different educational and ethical demands. It has been shown that students who go through this technological option of training also develop attitudes of ethicality in the creation of multi-modal educational materials and to ensure inclusiveness in the educational process, in line with the values and principles of modern education.

The research findings also show that the integration of different communication modes in the context of multimodal communication leads to the development of a dynamic interaction between these modes, each of them contributing to the possibility of a deeper perception of educational content. Students demonstrate an increasing ability to design multimodal environments that not only stimulate the cognitive and social development of children and students, but also provide opportunities for emotional, psychological, and personal development. This creates the conditions for the development of a synergistic process in which the different modalities interact and mutually enrich each other, and this integration not only improves the effectiveness of learning, but also provides a more complete and realistic opportunity for the formation of competence oriented to the modern multimodal world.

In order to improve the application of technology for the development of multimodal competence of future teachers, it is necessary to strengthen the integration of the practical application of multimodal approaches in the context of different disciplines. This can be achieved through the creation of cross-curricular projects and interactive learning scenarios that bring together knowledge and skills from different areas of learning, such as pedagogy, technology and digital communication. Through the implementation of such projects, students will have the opportunity to work with a variety of multimodal resources and develop greater flexibility in their application according to the context and needs of the learners.

In addition, in order to achieve a deeper development of the skills of designing and integrating multimodal resources, it is necessary to introduce specific methods of reflection and self-evaluation in the learning process. Students can be engaged in creating portfolios that include their multimodal projects as well as detailed analyses of the approaches used in them. Through such reflection, they will have the opportunity not only to evaluate the results of their work, but also to become aware of how different communication channels can be combined and adapted according to the requirements of the specific educational situation.

Finally, in order to improve the ethical aspect of multimodal technology implementation, it is important to strengthen learning initiatives that promote awareness of the ethical and social implications of using digital technologies in education. This includes the development of courses and workshops focused on issues of copyright, digital security and inclusivity in the educational process. Students must be prepared to create multimodal resources that are not only technologically sophisticated, but also aligned with ethical standards and values that ensure equitable access to knowledge and learning for all children and students.

The creation of multimodal resources enriches the educational process by integrating different

forms of communication - text, images, video, sound and interactive elements, which stimulates different channels of perception and learning. Artificial intelligence (AI) provides significant opportunities to adapt these resources to the individual needs of children and students, automating the processes of creating and personalising learning content. AI can analyze children/students' progress and generate dynamic and personalized learning experiences that change depending on their development and learning style. Despite these capabilities, there is a need for a concerted effort to build the skills to use AI effectively in the educational process. This includes both developing the technical competence to work with new technologies, and promoting critical thinking, ethical attitudes and responsibility in the use of AI in learning to ensure equal access and maximum benefits for all children and students, in the context not only of the classroom but also of the wider educational process.

Conclusions

The overall research focuses on the formation and development of multimodal competence in future teachers, applying a synergistic approach combining different modes of communication - verbal, non-verbal, visual and digital. Through a pilot study in the context of the educational disciplines "Pedagogy of Construction and Technology Activities" and "Productive Activities in Technical and Technological Education in Kindergarten and Grades 1-4", the possibility of developing these competencies through specialized technologies is explored. The focus is on the skills of creating, adapting and integrating multimodal resources as core components of competence, which include both technological and pedagogical skills for personalizing the educational process.

The results of the study show a statistically significant improvement in the skills of creating and integrating multimodal resources among students, which is confirmed through a comparative analysis of data before and after the implementation of the research methodology. The use of statistical tools, such as Wilcoxon's Test, demonstrates the success of the proposed technology for the development of multimodal competence, confirmed by the positive changes in both undergraduate and graduate students. This supports the thesis that the application of the transgressive synergistic model in education can effectively develop key skills needed to create innovative and dynamic educational resources.

Despite the results, the study highlights the need for focused efforts to continue to build skills in working with new technologies, including artificial intelligence. In order to maximise the benefits of these technologies, it is important that teachers are equipped to use them ethically and responsibly, while developing the skills to think critically and apply innovation to the educational process.

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Conflict of interests

The authors declare no conflict of interest.

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The Influence of The Family on the Development of a Criminal Personality

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Abstract: The family is the fundamental unit of structure and function in every society, as well as for each individual as a part of that society. As a primary social group, the family plays a key role in shaping an individual's personality and in the adoption of socially acceptable behavioral norms, while deviations in an individual's behavior toward criminal tendencies have always been a subject of interest to society as a whole. This paper analyzes the influence of the family environment on the development of a criminal personality, focusing on dysfunctional family relationships, neglect, domestic violence, lack of supervision, and negative behavioral patterns transmitted across generations. Drawing on theoretical foundations from contemporary criminology and developmental psychology, as well as analyzing numerous empirical studies conducted in various social and cultural contexts, this work aims to provide a comprehensive insight into how adverse family conditions - such as emotional neglect, violence, divorce, dysfunctional relationships, and lack of parental supervision - may contribute to the development of deviant behavior in children and adolescents, as well as the formation of antisocial personality traits. Although criminal behavior is a complex social phenomenon that cannot be attributed solely to family influence, the findings of this research confirm that the family environment plays a crucial role in the socialization process and in shaping an individual's moral compass. In other words, the family is recognized as one of the most influential factors in the formation of personal and social values that can significantly impact the development of criminal tendencies. The aim of this paper is to highlight the importance of prevention through the strengthening of family function and support for at-risk families as part of a strategy to combat criminal behavior.

Keywords: *criminal behavior, development of criminal personality, family, social environment, psychological factors.*

Introduction

The family is a fundamental social institution that performs numerous functions essential to the development of the individual and the preservation of social order. As the primary and first social environment in which a person begins to interact with others, the family has a profound influence on the formation of identity, the adoption of social norms and values, and the development of the emotional, cognitive, and social structure of personality. The processes that take place within family relationships-whether positive or negative-leave deep marks on an individual's development and influence future behavioral patterns, including those that may lead to deviance and criminality.

In this context, a criminal personality does not merely refer to a person who has committed a criminal offense, but to an individual who has developed personality traits that favor or encourage participation in criminal activities. Such traits include impulsiveness, aggressiveness, lack of empathy, antisocial tendencies, a propensity for manipulation, and disregard for social rules. A wide range of factors contribute to the emergence of these behavioral patterns-biological, psychological, social, and cultural-but among them, family factors are often the most significant and influential, particularly in early childhood and adolescence.

Dysfunctional family patterns-such as emotional neglect, physical or psychological abuse, authoritarian or overly permissive parenting styles, chronic parental conflict, divorce, alcoholism, substance abuse, and criminal behavior within the family-can significantly increase the risk of a child developing

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unacceptable forms of behavior. Lack of parental supervision, support, and a sense of security often leads children to seek belonging and validation in deviant peer groups, which can further steer them toward criminal activities. Additionally, families with low socioeconomic status, facing poverty, social exclusion, and marginalization, often lack the capacity to meet the child's needs in a way that ensures healthy personality development.

Modern criminology, sociology, and developmental psychology are increasingly focusing on this specific aspect-the relationship between the family environment and criminal behavior. Theories such as social learning theory, control theory, ecological development theories, and other approaches link the stability and quality of family relationships with the likelihood that an individual will develop antisocial or delinquent behavior. Numerous empirical studies confirm a correlation between dysfunctional family structures and the emergence of criminal behavior, especially during adolescence, a period when individuals are most vulnerable to the influence of their immediate environment.

However, it is important to emphasize that there is no simple or direct causal relationship between the family and criminality. Criminal behavior is a complex phenomenon that cannot be attributed to a single cause. Ultimately, criminology has firmly adopted the scientific view that every perpetrator of a criminal offense is driven by specific motives arising from both subjective and objective circumstances, as well as various contributing variables that may influence criminal behavior (Bjelajac, 2024). Many individuals who grow up in unfavorable family environments never become criminals, while some who come from functional and stable families still develop problematic behavior. For this reason, it is essential to view the influence of the family in interaction with other factors-individual, social, and economic.

The aim of this paper is to provide an analysis of the influence of the family on the development of a criminal personality, through a combination of theoretical and empirical approaches. The research will include a review of relevant literature, theoretical models, and research findings, as well as a critical analysis of the mechanisms through which family factors contribute to the formation of criminal behavior. Special attention will be given to the distinction between direct and indirect family influences, as well as to the possibilities for intervention and prevention at the family level.

Risk Factors Related to Parents and the Family

Some risk factors associated with the family are static, while others are dynamic. Static risk factors-such as a criminal history, parental mental health issues, or a history of childhood abuse-are unlikely to change over time. However, dynamic risk factors, such as poor parental behavior, domestic violence, or parental drug addiction, can be modified through appropriate prevention and treatment programs (Family-Based Risk and Protective Factors and their Effects on Juvenile Delinquency: What Do We Know?, 2008). Risk factors have cumulative and interactive effects: the more risk factors a family is exposed to, the more likely it is to be considered high-risk. Moreover, children and adolescents exposed to certain risk factors are also more likely to follow a life path that may lead to delinquent behavior (Wasserman et al., 2003). This is due not only to the accumulation of risk factor effects but also to their interaction: the effect of one factor amplifies the effects of another, and so on. For example, parental alcoholism can trigger family conflicts, which then increase the risk of substance abuse (Wasserman et al., 2003). There is extensive criminological literature suggesting that the family, as the basic building block of human society-especially the nuclear family-has a significant impact on child development. The family home is a natural school for children, where they internalize moral values through bonding, which are likely to guide their future development. Healthy and functional aspects of family life prevent antisocial behavior and/or delinquency, while the absence of proper parental care and negative parental influences, as well as growing up in dysfunctional families, may foster the development of such behaviors (Dragojlović and Matijašević, 2013). Certain conditions and practices can increase the likelihood of externalizing behavior in childhood, violence, aggression, and criminal conduct during later stages of developmen.

Tabela 1. *Juvenile delinquency risk factors associated with family according to age of children and adolescents*

Cumulative and interactive effects of risk factors				
Cumulative and interactive effects of risk factors		6-12 years	13-17 years	18 and older
	Family dynamic and functioning	• Poor parental practices • Parental and/or sibling criminality • Anti-social parents with attitudes that support violence • Family conflicts • Parents with substance abuse problems • Physical abuse and neglect • Family violence		• Poor parental practices • Parental and/or sibling criminality • Family violence • History of poor treatment
	Family characteristics	• Unstable family income • Broken home • Family mobility • Mental health of parents • Young mother • Number of children in the family • Single parent family • Parental past	• Unstable family income • Broken home • Family mobility	• Unstable family income
	Area of residence	• Poor area • Presence of young offenders	• Poor area • Crime in the area • Presence of youth gangs • Availability of drugs and firearms	• Poverty • Crime • Youth gangs • Drugs and firearms

Source: Family-Based Risk and Protective Factors and their Effects on Juvenile Delinquency: What Do We Know? (2008). Public Safety Canada. Retrieved April 5, 2025. https://www.publicsafety.gc.ca/cnt/rsrcs/pblctns/whtknw/index-en.aspx#a11

The table presents the cumulative and interactive effects of risk factors by age, divided into three developmental stages: children aged 6–12 years, adolescents aged 13–17 years, and young adults over 18 years of age. Risk factors are grouped into three main categories: family dynamics and functioning, family characteristics, and place of residence. The purpose of this classification is to highlight the complexity and interrelatedness of factors that negatively influence psychosocial development and potential delinquency among youth at different life stages. In all age groups, one of the dominant risk factors is inadequate parenting, manifested through a lack of supervision, authority, and emotional support. Among children and adolescents, particular risks include parental or sibling criminal behavior and the presence of parents who display antisocial attitudes or condone violence. Family conflicts, parental substance abuse, physical abuse and neglect, and domestic violence are additional destabilizing factors in the family environment. Among young adults over 18, the same patterns persist, with an added emphasis on a history of poor treatment during childhood and adolescence. For children aged 6–12, risk factors include unstable family income, broken families, frequent relocations, poor parental mental health, young mothers, large numbers of children in the household, single-parent households, and a negative family history. Among adolescents (13–17 years), risk factors remain similar with slightly fewer specific elements, while among young adults, economic instability remains the primary family-related risk. These findings suggest that early and chronic socioeconomic pressures have long-term consequences for development.

The table indicates that risk factors accumulate throughout childhood, adolescence, and early adulthood, with some early risks (e.g., poverty, domestic violence, neglect) persisting into later developmental stages. Moreover, there is interaction between personal, familial, and societal factors, creating a multifaceted burden that can contribute to the development of antisocial behavior. Understanding these connections is essential for designing comprehensive prevention and intervention programs targeted at vulnerable youth groups.

Based on the above, criminal behavior emerges as a multilayered phenomenon influenced by the dynamic interaction of individual, social, economic, and environmental factors. Among the most formative and enduring influences is the family environment, particularly the roles played by parents and primary caregivers. The family is the first and most important social unit in a child's life, laying the foundation for behavioral patterns, emotional regulation, socialization processes, and moral values. It is within this microcosm that children first encounter the concepts of authority, discipline, empathy, and responsibility.

Dysfunctional family dynamics - such as neglect, abuse, lack of supervision, or deviant parental behavior - although not the sole cause, are consistently associated with the emergence and escalation of deviant and criminal behavior. Longitudinal studies, meta-analyses, and cross-cultural research over the past several decades have further confirmed that the family environment is not only a risk or protective factor in isolation, but also a context in which other ecological and psychological risks converge and interact (Farrington and Malvaso, 2023). This chapter aims to thoroughly examine the various family risk factors that contribute to the development of criminal behavior, integrating classical criminological theories with contemporary empirical findings.

Parental supervision and self-control are among the most critical protective factors against delinquency. When supervision is lacking, children may fail to internalize social norms, face inconsistent consequences for misbehavior, or seek approval from deviant peer groups. Effective parental supervision involves awareness of a child's whereabouts, peer associations, and daily activities, playing a key role in preventing opportunities for antisocial behavior (Patterson, DeBaryshe and Ramsey, 1989). In this sense, the family environment and parental supervision serve as the first "safety measure" against antisocial behavior.

From a theoretical perspective, Hirschi's social control theory argues that strong emotional bonds between children and their parents inhibit deviant behavior. These bonds are nurtured through consistent monitoring, emotional support, and the establishment of rules. When such bonds weaken, children become more susceptible to external pressures, including delinquent peer groups.

Complementing this view, the *General Theory of Crime* by Gottfredson and Hirschi (1990) emphasizes that self-control, largely developed in early childhood through effective parenting, is a key factor in criminal behavior. Poor parental supervision, lax discipline, and failure to model appropriate behavior can lead to the development of low self-control-a trait associated with impulsivity, aggression, and lack of foresight-characteristics often found among offenders.

Moreover, recent studies emphasize that the harmful effects of poor supervision are amplified in contexts of socioeconomic hardship, where external stressors already strain family relationships (Farrington and Malvaso, 2023). Therefore, targeted interventions that strengthen parental involvement and teach supervision skills are essential components of delinquency prevention strategies.

Parenting styles and practices refer to the ways in which parents or caregivers interact with their children. Certain styles and practices appear more likely than others to lead to delinquency, and can therefore be considered risk factors (Merdović, Počuča, Dragojlović, 2024; Hart et al., 1998). While parenting practices refer to specific behavioral patterns of parents, parenting styles relate to parent-child interactions that reflect parents' attitudes toward their children and the emotional climate of the relationship (Baumrind, 1991). The four main parenting styles are: authoritarian, permissive, neglectful/uninvolved, and authoritative.

Parenting style-defined by the dimensions of responsiveness (warmth) and demandingness (control)-is widely recognized as a determinant of youth behavioral outcomes. Baumrind's typology describes four principal parenting styles: authoritative, authoritarian, permissive, and neglectful (Baumrind, 1991). Among these, authoritative parenting, which balances firm boundaries with emotional support, is consistently associated with the lowest levels of delinquency and antisocial behavior.

Contemporary research further supports and elaborates on this approach. A cross-European study from 2023 showed that both authoritative and permissive parenting (high warmth, low control) were linked with positive outcomes among adolescents, including lower levels of externalizing behavior. In contrast, authoritarian (low warmth, high control) and neglectful (low warmth, low control) styles were associated with increased delinquency-especially when coupled with high family stress or instability, both social and economic.

Moreover, changes in parenting style over time-such as a shift from authoritative to disengaged parenting due to divorce, unemployment, or mental health issues-can have significant negative effects. A longitudinal study by Schroeder and Mowen (2014) found that such changes are linked to weakened attachment, reduced parental influence, and an increased risk of delinquency.

Attachment theory, developed by Bowlby (1982), emphasizes the psychological mechanisms underlying these outcomes. Secure attachment, fostered through responsible and consistent caregiving, promotes emotional stability and social competence. In contrast, insecure or disorganized attachment-often the result of neglect, inconsistent care, or abuse-is correlated with anxiety, aggression, and difficulty forming trusting relationships. Lyons-Ruth et al. (1993) further observed that disorganized attachment in childhood predicts hostile and aggressive behavior in preschool years, which may evolve into delinquency during adolescence.

Family structure and stability have a significant impact on children's developmental trajectories.

Incomplete families-such as those with single parents, divorced or remarried parents, or frequent changes in guardianship-are often associated with an increased risk of delinquency. However, recent research emphasizes that it is not the family structure itself that matters most, but rather the quality of relationships and the level of parental involvement within that structure.

Demuth and Brown (2004) pointed out that although adolescents from single-parent or blended families show higher rates of delinquency than those from two-parent households, much of this difference is explained by variations in supervision, attachment, and economic resources. A 2022 Swedish population study confirmed that adolescents living in complex, asymmetrical family structures are more prone to

delinquent behavior, but also noted that strong parent-child attachment mitigates this risk (Svensson and Johnson, 2022).

There is strong evidence that family instability, marked by frequent relocations, parental conflict, or shifts in living conditions, has a disruptive impact on children's psychological well-being. Exposure to chronic parental conflict or domestic violence creates a climate of fear and insecurity, fostering maladaptive coping strategies such as aggression, defiance, and emotional withdrawal (Jaffe, Wolfe and Wilson, 1990).

The cumulative impact of family instability can erode trust in authority, reduce academic achievement, and increase affiliation with deviant peer networks, thereby heightening the risk of criminal involvement.

Parental criminality and substance abuse are among the most significant intergenerational predictors of delinquency. Children learn behavior through observation and imitation, as outlined in Bandura's Social Learning Theory (1977). When parents themselves engage in criminal or addictive behavior, children may internalize such conduct as normative-perceiving it as normal and acceptable behavior to be emulated (Ibid).

Empirical studies have consistently shown that children of incarcerated parents or those who abuse substances face a higher risk of various adverse outcomes, including academic failure, mental health disorders, and criminal behavior (Murray and Farrington, 2005). Farrington and Malvaso (2023) further observe that the combination of parental convictions and authoritarian discipline is particularly predictive of juvenile delinquency.

Parental substance abuse also creates a home environment characterized by emotional unavailability, neglect, and often violence. These conditions undermine the formation of secure attachments and reduce the likelihood that parents will provide consistent discipline, support, or supervision (Pearson, D'Lima and Kelley, 2012). Children raised in such settings often experience trauma, instability, and social isolation-all of which contribute to criminal trajectories. Due to this familial environment, children tend to normalize the criminal milieu, where substance abuse, alcohol misuse, and frequent incarceration are part of daily life. As a result, they are less likely to perceive such behaviors as unacceptable.

Although **economic hardship and family stress** do not constitute a direct or immediate cause of criminal behavior, they create an environment in which numerous other risk factors are intensified and activated, potentially leading to the development of deviant patterns. According to the Family Stress Model, economic difficulties result in increased levels of parental stress, frustration, and intra-family conflict, which in turn undermine the quality of parenting practices and increase the likelihood of problematic behaviors in children (Conger et al., 1992).

Financial instability often leads to reduced emotional and cognitive involvement of parents in upbringing, more frequent use of punitive or even violent discipline, and limited capacity to provide an enriching socio-educational environment. Such families frequently lack access to essential social and health services, including mental health support, quality education, and extracurricular programs that serve a preventative function. Farrington and Malvaso (2023) emphasize that the synergistic effect of economic hardship and factors such as harsh parenting or a family history of criminality significantly increases the risk of juvenile delinquency.

Empirical evidence from evaluations of social interventions-such as the Perry Preschool Project, Elmira Nurse–Family Partnership, and Multisystemic Therapy (MST)-shows positive long-term effects in reducing delinquency levels. These programs succeed by enhancing parenting skills, stimulating early educational development, and targeting structural deficits in the social and familial context (Henggeler et al., 2009).

These interventions point to the need for a holistic, multidimensional approach that combines individualized family support with broader social and legal reforms. Such an approach aligns with modern understandings in the fields of criminal justice and social policy, which emphasize the importance of preventative action through reducing social exclusion and strengthening family-based protective factors.

Abuse, neglect, and traumatic experiences represent the most severe forms of family dysfunction and are strongly linked to both immediate and long-term behavioral problems. Physical abuse, emotional abuse, sexual abuse, and chronic neglect disrupt healthy psychological development, often resulting in emotional dysregulation, aggression, and impaired interpersonal functioning (Widom, 1989).

The "cycle of violence" hypothesis suggests that individuals who experience abuse are more likely to engage in violent or criminal behavior later in life. This intergenerational transmission of violence is supported by a growing body of neurobiological and psychological evidence indicating that early trauma alters brain development, stress response systems, and moral reasoning. Contemporary studies also explore how exposure to harsh disciplinary practices-such as frequent yelling, humiliation, or physical punishment-can lead to the development of dark personality traits, including narcissism, Machiavellianism, and

psychopathy, all of which are associated with criminal behavior. Children exposed to neglect, meanwhile, often struggle with attachment disorders, cognitive delays, and a lack of social competence, increasing their risk of peer rejection and involvement in delinquent subcultures (Dubowitz et al., 2002). Intervention programs that address trauma through therapeutic, educational, and family-based approaches have been shown to reduce behavioral problems and improve resilience in at-risk children.

Siblings are among the longest-lasting relationships in most people's lives - from early childhood to old age. Older blood relatives play an important role in the development and adjustment of children and adolescents, including the emergence of problematic behavior. This influence arises not only from frequent and often emotionally intense interactions, but also from the **impact of siblings** and their role in the dynamics of family relationships, which can sometimes be highly complex. It is well known that siblings often imitate one another, with younger children most commonly mimicking their older brothers and sisters. Therefore, it is reasonable to assume that such direct and/or indirect influences and their variations play a significant role in shaping the development of aggressive behavior. Compared to the influence of peers, parents, and schools, this factor has been less explored, even though many studies indicate that sibling delinquency is closely linked to adolescent delinquency, especially in early adolescence. In general, siblings learn from one another, with younger children predominantly learning from older ones (Bjelajac, 2023, pp. 66–67). This domain of influence on the formation of delinquent behavior in adolescents is particularly evident in the adoption of risky behavior patterns such as alcohol consumption, smoking, use of psychoactive substances, and early sexual activity. The first signs of such influence are often observed in neglect of school responsibilities and reduced commitment to education. In contrast, functional family relationships, including consistent parenting styles and emotional closeness and support among siblings in early childhood, are associated with the development of numerous prosocial behaviors and more favorable life outcomes.

We have emphasized that parents likely have one of the greatest influences on a child's life. The development of children is significantly shaped by both the biological and psychosocial aspects of parenting, including **parental psychopathology** (Ollendick and Herson, 1989). In this regard, it is not surprising that parents and children often exhibit similar psychopathological symptoms. Why do we observe this connection between parental and child psychopathology? The reason may lie in the fact that children learn, imitate, and internalize dysfunctional parental behaviors. Children are at the greatest risk of developing the type of psychopathology demonstrated by their parents due to environmental influences and patterns such as parental modeling (Burstein, Ginsburg, and Tien, 2010; Burstein et al., 2010). Parental psychopathology has been observed to be a strong predictor of child psychopathology. Children of parents with anxiety or depressive disorders are more likely to be diagnosed with similar disorders than children whose parents do not suffer from these conditions. The likelihood of a child developing a disorder is five to six times higher if the parent has anxiety, depression, or both (Beidel and Turner, 1997).

It is therefore evident that, in a significant number of cases, there is a strong connection between childhood depression and anxiety and parental psychopathology. Even parental alcoholism increases the risk of various negative outcomes in children. The presence of paternal alcoholism, in particular, can contribute to antisocial behavior and maladjustment in sons (Bjelajac, 2023, p. 68). Accordingly, it is observed that parents with a history of mental illness can influence child development through various mechanisms. Understanding these influences can play an important role in shaping early intervention programs and preventive strategies aimed at reducing anxiety and depression among children.

According to the U.S. Census Bureau (2022) (Single Mother Statistics, 2023), *single-parent households have become an accepted way of life*. Approximately 11 million families with children under the age of 18 live in single-parent households. The data show that vulnerable single motherhood has become so common in the United States that 80 percent of single-parent households are led by single mothers, with nearly one-third living in poverty. Two-parent households may be broken due to various circumstances - death, abandonment, divorce, or separation. At the same time, there is a growing number of women who deliberately avoid marital relationships and conceive through anonymous donors, framing this choice as an act of free will and a modern lifestyle, even though such decisions may be detrimental to the biopsychological development of the child. This is symptomatic because many authors reveal data showing that delinquency is more likely among children from homes where parents are divorced or separated. Thus, it can be concluded that a single-parent or broken home, as some describe it, may induce criminal behavior, especially when interacting with other risk factors (Bjelajac, 2023, pp. 62–63).

As can be seen, the influence of the family on the development of criminal behavior is profound and multifaceted. While healthy, supportive, and structured family environments act as strong protective factors, dysfunctional family dynamics significantly increase the risk of delinquency and criminal activity. Poor parental supervision, ineffective parenting styles, family instability, parental criminality, economic hardship, and exposure to abuse and neglect all contribute to a child's vulnerability to antisocial behavior.

It is important to note that these risk factors rarely operate in isolation. Their interaction often amplifies their effect, creating a range of challenges that hinder normative development. Addressing these issues requires early, comprehensive, and context-sensitive interventions that support families in building nurturing environments. Prevention strategies must focus not only on the individual but also on enhancing parenting skills, improving family stability, reducing economic disparities, and delivering trauma-informed care.

Quantifying the Impact of the Family on the Development of a Criminal Personality

Quantifying the impact of the family on the formation of a criminal personality involves assessing the extent to which family factors statistically predict, correlate with, or contribute to the development of antisocial traits and criminal behavior.

Although no single variable can fully explain criminal behavior, a growing body of research has identified consistent familial predictors-such as parenting quality, family structure, and parental criminal history-that correlate with an increased likelihood of criminal outcomes (Farrington, 2002; Murray and Farrington, 2005). These findings underscore the central role of the early family environment in individuals' social development and their potential deviation from societal norms. This chapter explores how these factors are quantified, the strength of their associations, and their interaction with individual and environmental variables in shaping criminal personality.

Longitudinal and cohort studies provide some of the most robust evidence for quantifying the influence of the family. These studies follow individuals over extended periods and track various familial and behavioral variables, allowing researchers to identify causal links rather than mere correlations.

One of the most frequently cited studies is the *Cambridge Study in Delinquent Development*, led by David Farrington, which followed 411 boys from working-class families in London from childhood into adulthood. The study revealed that children from families with poor parental supervision, harsh discipline, and a parental criminal background were significantly more likely to be convicted of crimes later in life (Farrington, 2002). The study quantified that approximately 6% of families accounted for more than 50% of all convictions within the cohort, illustrating the concentrated nature of familial risk and the disproportionate impact of certain family environments.

Similarly, the *Pittsburgh Youth Study* (PYS) and the *Dunedin Multidisciplinary Health and Development Study* from New Zealand provided quantitative data linking poor parenting, parental substance abuse, and early family adversity with persistent criminal behavior. These studies often utilize multivariate regression analyses to isolate the effects of family variables from other predictors such as socioeconomic status or school environment (Loeber et al., 2008; Moffitt, 1993). Such analytical separation helps to more precisely determine the unique contribution of family variables in the trajectory toward criminality.

The predictive strength of parental criminality is one of the most powerful familial predictors of future offending. Murray and Farrington (2005) analyzed data from multiple cohort studies in the UK and US and found that children of convicted parents were more than twice as likely to be convicted themselves, even after controlling for socioeconomic factors. This suggests a strong intergenerational transmission of criminal behavior.

A meta-analysis conducted by Besemer et al. (2011) found that the odds ratio for intergenerational transmission of criminal behavior was approximately 2.4, indicating a moderate to strong predictive association. This transmission is attributed not only to genetic factors but also to behavioral modeling within the family, social stigma, and shared adverse conditions. Children who grow up observing criminal behavior may internalize such behaviors as acceptable, especially in the absence of positive role models.

Quantitative findings from the Cambridge study also showed that 63% of boys whose fathers had criminal convictions were later convicted themselves, compared to only 30% among those whose fathers had no criminal record (Farrington, 2002). These figures demonstrate that a parental criminal history represents a strong risk marker that further exacerbates other adverse conditions.

Various criminological models and risk assessment tools include family variables as part of

their predictive algorithms. For example, the *Youth Level of Service / Case Management Inventory* (YLS/CMI) includes family circumstances and parenting style as key domains of risk, emphasizing that the family is not merely a contextual background but a quantifiable determinant of youth outcomes.

In actuarial risk assessments, family-related indicators are often weighted according to their statistical correlation with delinquent outcomes. These models typically assign higher risk scores to youth who experience neglect, inconsistent parenting, or have parents with a criminal history. Studies evaluating the predictive validity of these tools have shown that including family variables increases the accuracy of predictions regarding recidivism and persistent criminal behavior (Schmidt et al., 2011).

Multivariate regression models and structural equation modeling (SEM) techniques are also frequently used in academic research to quantify the relative contribution of family factors. For instance, Loeber et al. (2008) used SEM to demonstrate that poor parental supervision significantly mediates the relationship between socioeconomic disadvantage and juvenile delinquency. These advanced statistical methods allow researchers to visualize both direct and indirect effects within complex systems of variables.

Quantification of parenting quality and its outcomes-i.e., attempts to measure the quality of parenting-often involves multi-item questionnaires and observational checklists. Among them are the *Alabama Parenting Questionnaire* (APQ) and the *Parenting Scale*, which assess dimensions such as positive involvement, inconsistent discipline, and poor supervision. These tools provide quantitative metrics that can be linked to behavioral outcomes in youth.

Meta-analyses of such studies have shown moderate to strong correlations between poor parenting practices and antisocial behavior. For example, Hoeve et al. (2009), in a meta-analysis of 161 studies, found that poor parental supervision had a medium effect size of r = .23 in predicting delinquency, while harsh discipline had an effect size of r = .19. These findings are statistically significant and consistent across multiple samples, thereby strengthening the reliability of these associations.

Although moderate, these effects carry substantial weight in behavioral sciences and indicate that family-based interventions can significantly reduce youth offending when parenting quality is improved. Intervention programs that enhance parenting practices-such as consistent discipline, emotional support, and supervision-can serve as highly effective strategies for crime prevention.

In the context of the cumulative and interactional nature of risk factors, it is observed that family-related risk factors rarely operate in isolation. Instead, they interact with other domains such as peer influence, education, and community conditions to either amplify or mitigate risk. This cumulative risk model is supported by studies showing that the presence of multiple risk factors exponentially increases the likelihood of criminal behavior (Rutter, 1979).

In the *Rochester Youth Development Study*, youth exposed to three or more family risk factors exhibited delinquency rates more than four times higher than their peers without such factors (Thornberry et al., 2003). These findings have led to the use of cumulative risk indices in research and policy to better capture the degree of vulnerability within families. The more adverse conditions a child experiences, the greater the likelihood of behavioral and emotional problems that may lead to criminality.

Additionally, research conducted by Farrington and Malvaso (2023) highlights how combinations of family risk factors-such as parental criminality, harsh parenting, and poverty-interact and significantly increase the probability of juvenile delinquency, more so than any single factor alone. These interaction effects underscore the need for holistic interventions that address multiple dimensions of family dysfunction.

Thus, quantifying the impact of the family on the formation of a criminal personality requires a nuanced synthesis of theoretical models and empirical data. Through numerous longitudinal and meta-analytical studies, family variables-particularly parenting style, parental criminal history, and family stability-have consistently shown moderate to strong associations with criminal behavior.

The predictive strength of these variables varies depending on the population and cultural context but remains significant even when controlling for other social and economic factors. While no single measure can fully capture the complexity of criminal development, combining risk assessment tools, the cumulative risk model, and longitudinal tracking enables better understanding, prediction, and ultimately, prevention of criminal behavior stemming from the family environment.

These insights also emphasize the crucial importance of early interventions and family-based prevention programs. By identifying at-risk families and providing targeted forms of support, policymakers and social workers can interrupt the trajectory from family dysfunction to criminal outcomes, thereby fostering healthier developmental paths for vulnerable children.

Protective Factors as a Response to Risk Factors

The complex interplay between individual, familial, interpersonal, and societal dynamics contributes significantly to the risk of youth violence. Many risk factors associated with violent behavior among young people are closely linked to prolonged exposure to toxic stress, which adversely affects brain development in children and adolescents. Such toxic stress may arise from various adverse conditions faced by youth, including poor living environments, substance abuse, and other forms of instability (Bjelajac, 2023, p. 81).It is essential to recognize that no effort aimed at preventing criminal behavior can be effective or sustainable unless it addresses the underlying causes of such behavior. The elements that serve as a buffer between the presence of risk factors and the onset of delinquency are known as protective factors (Bjelajac, 2023, pp. 82–83). Risk factors are negative influences that affect individuals or communities, potentially leading to increased levels of crime, victimization, and fear within society. Conversely, protective factors are positive influences that enhance individual well-being and community safety, reducing the likelihood of criminal involvement or victimization. Strengthening and reinforcing existing protective factors contributes to the resilience of both individuals and communities, enabling them to better withstand and manage exposure to risk. This approach highlights the importance of proactive strategies that focus not only on mitigating risk but also on fostering protective environments and relationships (Family-Based Risk and Protective Factors and their Effects on Juvenile Delinquency: What Do We Know?, 2008; Kovačević Lepojević, Merdović, and Živaljević, 2022).

Considering that resilience to stress and negative influences varies from person to person, and that young people are constantly exposed to numerous challenges and risk factors, the question arises: to what extent is an individual's psychophysical structure capable of withstanding such pressures? Early identification of risk and the development of protective mechanisms play a crucial role in building resilience, with the family environment being particularly significant. Prevention within the family-through supportive relationships, open communication, stable emotional bonds, and active parental care-forms the foundation for the development of healthy behavioral patterns in children and adolescents.

Although the education system, community, and society at large are also important, research shows that timely measures within the family context can significantly reduce the risk of delinquent behavior. Ongoing parental education, strengthening of family competencies, and raising awareness about the importance of a safety-oriented culture are key components of preventive strategies that are both sustainable and effective over the long term. Prevention that begins in the home often has the most far-reaching impact on protecting young people and guiding their development in a positive direction. The family environment, as the earliest and most enduring developmental anchor, plays a fundamental role in shaping the attitudes, values, and behavioral patterns of children and adolescents. The multiple challenges of contemporary society-from substance abuse and digital violence to extremist narratives and technological misuse-highlight the need for resilience and responsible behavior to be cultivated first and foremost within the family (Bjelajac and Jovanović, 2013; Bjelajac and Filipović, 2020; Bjelajac, Matijašević and Počuča, 2012; Zirojević and Bjelajac, 2013).

The narrative of the development and prevention of criminal behavior involves complex cause-and-effect relationships that do not allow for simple solutions. Certain risk factors-such as global economic disruptions or high unemployment rates-are often structurally conditioned and resistant to rapid change. Numerous studies point to a correlation between low socioeconomic status and an increased likelihood of antisocial and deviant behavior.

Table 2. *Protective factors associated with family*

Family dynamic and functioning	Family characteristics	Area of residence
• Relationship based on family bond • Positive support within the family • Adequate parental supervision • Respect for friends by parents • Closeness between parents and children (affection) • Consistent disciplinary methods • Adequate parental behaviour and practices	• Parental level of education • Financial stability • Stability of the family unit	• Integration of families into the life of the community • Relationships established with neighbours • School activities involving the family

Source: Family-Based Risk and Protective Factors and their Effects on Juvenile Delinquency: What Do We Know? (2008). Public Safety Canada. Retrieved April 5, 2025. https://www.publicsafety.gc.ca/cnt/rsrcs/pblctns/whtknw/index-en.aspx#a11

Nevertheless, there are also risks that can be mitigated through targeted intervention, such as deficits in parental competencies. Through educational programs and professional support, it is possible to improve parenting skills and thereby strengthen the family environment as an important protective factor. Since risks emerge at various levels-individual, familial, school-based, and broader societal-protective measures must also be multilayered, coordinated, and tailored to specific challenges. Naturally, such approaches have their limitations, but they represent an important step in the strategic prevention of criminal behavior, particularly when it comes to vulnerable youth populations.

Materials and Methods

As part of the implementation of this descriptive research, research questions were formulated with the aim of enabling a systematic examination of the family's influence on the formation and evolution of criminal behavior. Through the application of qualitative research methods-primarily content analysis, case studies, and in-depth analytical approaches-it was possible to explore the complex social and psychological processes underlying the development of deviant and antisocial behavior patterns within the family environment. The intent was to ensure a holistic and interdisciplinary understanding of the phenomenon in question.

The goal of this approach was to provide well-argued answers to the research questions through contextualized and detailed interpretation, in direct correlation with the primary aim of the paper: to identify and analyze the influence of the family on the development of a criminal personality, as well as the mechanisms of its effect in the context of the emergence and progression of an individual's criminal behavior.

Additionally, by using the method of comparative analysis, the research facilitated a better understanding of the layered and multifactorial nature of criminality, as well as the role, place, and influence of the family in the development of a criminogenic personality. It also pointed to contextual and cultural specificities that may influence variations in the etiology of criminal behavior.

For the purpose of this paper, the survey has been designed and conducted, between February 17, 2025 and June 2, 2025, with a sample of **395 students** from the Faculty of Law for Commerce and Judiciary in Novi Sad. *The purpose of the survey was to examine students' perceptions of key family-related factors contributing to the formation of a criminal personality.* The survey question, the students, had to answer was: *Which of the following family-related factors, in your opinion, contribute most to the development of criminal behavior among young people? (Select up to three factors you consider the most important.)* An overview and the results will be presented and discussed at the relevant part of the paper.

Results

The research was conducted from February 17, 2025, to June 2, 2025, on a sample of **395 students** from the Faculty of Law for Commerce and Judiciary in Novi Sad. *The purpose of the survey was to examine students' perceptions of key family-related factors contributing to the formation of a criminal personality.*

Survey Question: *Which of the following family-related factors, in your opinion, contribute most to the development of criminal behavior among young people? (Select up to three factors you consider the most important.)*

Response Options:

1. Abuse, neglect, and traumatic childhood experiences
2. Parents' mental illness (parental psychopathology)
3. Lack of emotional connection with parents
4. Domestic violence among family members
5. Alcoholism or addiction of one or both parents
6. Poverty and poor material conditions
7. Lack of parental control and supervision
8. Criminal history of the parents
9. Divorce and dysfunctional family dynamics
10. Absence of one parent (e.g., physical or emotional)

Table 3. Survey Results (most frequently selected answers, by number of responses)

No.	Risk factor	Results	Percentage
1	Abuse, neglect, and traumatic childhood experiences	93	23,6%
2	Parents' mental illness (parental psychopathology)	81	20,6%
3	Lack of emotional connection with parents	15	3,8%
4	Domestic violence among family members	31	7,8%
5	Alcoholism or addiction of one or both parents	27	6,8%
6	Poverty and poor material conditions	25	6,3%
7	Lack of parental control and supervision	19	4,8%
8	Criminal history of the parents	74	18,7%
9	Divorce and dysfunctional family dynamics	17	4,3%
10	Absence of one parent (e.g., physical or emotional)	13	3,3%

Source: Author's calculation

The survey presented in Table 3 identifies the most frequently selected risk factors perceived to influence negative outcomes in individuals, such as deviant behavior, social maladjustment, or psychological disorders. The respondents' answers highlight a clear pattern: the family environment, especially during childhood, plays a central role in shaping an individual's development and future behavior.

The most frequently identified risk factor is "Abuse, neglect, and traumatic childhood experiences", selected by 23.6% of respondents. This indicates a strong recognition of the lasting effects that early trauma can have on a child's emotional, social, and psychological development. Childhood maltreatment is often linked to disruptions in attachment, emotional regulation difficulties, and a higher likelihood of adopting maladaptive coping strategies. The second most cited risk factor is "Parents' mental illness (parental psychopathology)" at 20.6%, suggesting that the psychological well-being of caregivers is seen as critical to a child's healthy upbringing. Children growing up with mentally ill parents may be exposed to instability, emotional unavailability, or even unsafe environments, all of which can lead to developmental delays or behavioral issues. Closely following is "Criminal history of the parents", at 18.7%. This reinforces well-established criminological theories regarding the intergenerational transmission of criminal behavior. Such environments often normalize antisocial behavior and may expose children to high-stress situations, poor role models, and social marginalization.

The dominance of these top three risk factors underscores a key insight: adverse family conditions, particularly in early childhood, are perceived as the most influential contributors to negative life outcomes. The responses reflect a biopsychosocial understanding of human behavior, where biological vulnerabilities (e.g. inherited mental illness), psychological trauma, and social influences (e.g. criminal behavior modeled by parents) interact in complex ways.

Mid-ranking factors such as domestic violence (7.8%), alcoholism or addiction (6.8%), and poverty (6.3%) are also critical, though perceived as somewhat less directly damaging than abuse or parental mental illness. These factors contribute to household instability and increase the likelihood of emotional distress, neglect, or exposure to harmful situations.

Less frequently mentioned were lack of emotional connection (3.8%), divorce or dysfunctional family dynamics (4.3%), and absence of a parent (3.3%). While these can also negatively affect children, they may be seen as more manageable or less inherently damaging, particularly if mitigated by other protective factors (e.g. support from extended family, school, or community).

The survey results support existing psychological and sociological research emphasizing the importance of early childhood experiences and parental influence. They suggest that policies and interventions should focus on preventing child abuse, supporting families affected by mental illness, and disrupting cycles of intergenerational criminality. This can be achieved through trauma-informed care, mental health services for parents, social work interventions, and targeted education or mentorship programs for at-risk youth.

Furthermore, the relatively low frequency of responses related to divorce or single parenting may indicate a shift in societal attitudes, reflecting increased normalization of these family structures and a more nuanced understanding that their impact depends on context, not merely presence.

In conclusion, the table provides valuable empirical support for the view that family environment-

especially when marked by trauma, mental illness, or criminal behavior-is a central risk factor for developmental and behavioral challenges. Future research and social policy should prioritize early intervention and holistic family support as preventive measures.

Discussion

The previous chapters have provided a comprehensive overview of how the family influences the formation of a criminal personality-from identifying basic risk factors, through their detailed explanation, to attempts at quantification through longitudinal and empirical research. In this discussion, we will analyze how all these findings together contribute to our understanding of the phenomenon, and what dilemmas, limitations, and opportunities emerge for further research and action.

The chapter dedicated to family risk factors demonstrated that dysfunctional family patterns-such as neglect, domestic violence, chronic conflict, emotional detachment, and poor behavioral control-have a clear correlation with an increased likelihood of developing antisocial behavior in children. These findings serve as the foundation for understanding the criminogenic role of the family, as well as a basis for identifying at-risk groups. Even at this stage of the paper, a crucial question arises: are these factors causes, triggers, or merely indirect indicators of deeper socioeconomic problems? The answer is not straightforward, which points to the need for multilayered models of analysis that also account for the broader social context. The chapter focusing on quantitative approaches raises the issue of the measurability of family factors and their predictive power regarding criminal behavior. Studies such as the Cambridge, Dunedin, or Pittsburgh Youth Study offer compelling evidence of the significance of the family environment. Still, no matter how impressive the numbers-such as findings showing that children of convicted parents are twice as likely to be convicted themselves-quantification comes with certain limitations. For instance, there is the risk of overgeneralization, the neglect of cultural context, and the overlooking of individual protective factors. In other words, numbers speak, but they do not explain everything.

A shared theme of both chapters is the emphasis on early childhood and formative family relationships as key determinants of personality development. However, what especially deserves attention is the interaction among risk factors, their overlap, and their cumulative effects. It is precisely this complexity that explains why uniform solutions and approaches often fail to yield long-term results. The family is not an isolated system-it functions within an environment shaped by economic, cultural, and political influences. Therefore, any consideration of family-related factors must be broadened to include the wider societal framework.

From the current analysis emerges a need to balance two narratives: the narrative of risk and the narrative of resilience. While it is important to identify at-risk families, it is even more important to empower them-not through exclusion, but through inclusive policies and support. In this sense, quantitative research should not be used to stigmatize, but rather to enable early identification of needs and the development of preventive programs. Additionally, it is important to ask who produces, interprets, and uses data about family factors. Are they experts, policymakers, or institutions that often operate through a punitive rather than a preventive logic? If family factors are known to have predictive power, then it would be logical for society to invest in prevention-not solely in repressive mechanisms.

In conclusion, the key contribution of the previous chapters lies in the integration of various theoretical and empirical perspectives, which call for a holistic understanding of the family as a space where both risk and protective factors simultaneously develop. The family can play an ambivalent role-it can be a supportive environment for healthy development, but also a source of dysfunction and destructive behavior. In this light, the survey conducted among 395 students at the Faculty of Law for Commerce and Judiciary in Novi Sad further highlights this complexity, confirming that abuse, neglect, and parental psychopathology are recognized as dominant risk factors in the formation of a criminal personality. These findings call for continued dialogue between theory and practice, between statistics and life stories, and point to the urgent need for prevention that begins within the family environment.

Conclusion

The analysis of family factors in the context of criminal behavior reveals a complex and multilayered picture in which the family plays a key-but not exclusive-role in the formation of criminal personality. Through a review of theoretical approaches, the identification of specific risk factors, and their empirical quantification, this paper demonstrates that while the influence of the family is undeniably strong, it must be understood within a broader social and individual context.

The family represents the first and most intense social environment that shapes a child's values, norms, and behavior patterns. Through early emotional relationships with parents and other family members, a child develops foundational models that later influence their decisions and actions. In this sense, it has been shown that factors such as parental supervision, emotional warmth, consistent discipline, and the absence of violence are key protective elements that reduce the risk of criminal behavior. On the other hand, dysfunctional family patterns-including violence, neglect, parental criminality, and chaotic family structure-represent risk factors that significantly increase the likelihood of developing antisocial traits and behaviors. Although these factors do not predetermine an individual's fate, their presence contributes significantly to the cumulative effect of risk, especially when protective factors from other life spheres (school, community, peer relationships) are lacking.

Empirical research, including longitudinal studies such as the Cambridge Study, the Dunedin Multidisciplinary Health and Development Study, and the Pittsburgh Youth Study, has enabled the quantification of family-related factors and confirmed their predictive power. Based on these findings, it is clear that certain forms of parental behavior and family dynamics can be considered early indicators of risk for criminal development.

However, it is important to emphasize that quantification must not lead to a deterministic approach. No child is doomed to a criminal path simply because they come from a high-risk family. This is precisely why it is necessary to develop and implement policies that not only identify at-risk cases but also provide active support to families in crisis situations. Prevention must be holistic, systemic, and long-term, with a focus on strengthening family competencies, promoting positive parenting, and reducing socioeconomic inequalities.

In conclusion, it can be said that the family has the potential to be both the cause and the solution to the problem of criminality. It can be a source of serious difficulties and risk factors, but also a space from which resilience, support, and the opportunity for change emerge. Criminological policies that recognize this and act accordingly are more likely not only to reduce crime rates but also to contribute to a healthier and more just society overall. Ultimately, strengthening the family unit remains one of the most effective means of preventing youth delinquency and breaking the intergenerational cycle of criminal behavior.

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Authors contribution

Conceptualization, Ž.Đ.B., J.D. and D.K.; methodology, Ž.Đ.B. and J.D.; software, D.K.; formal analysis, Ž.Đ.B. and J.D.; writing-original draft preparation, Ž.Đ.B. and J.D.; writing-review and editing, J.D. and D.K. All authors have read and agreed to the published version of the manuscript.

Conflict of interests

The authors declare no conflict of interest.

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The Role of Education and the Digital Era in Reducing the Economic Gap and Gender Inequality

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Abstract: This paper explores the role of education and the digital era in reducing the economic gap and gender inequality. The main objective is to analyze how modern educational practices, combined with access to digital technologies, can contribute to the economic empowerment of women and the reduction of gender-based discrimination. The focus is placed on three interconnected areas: income disparity, access to digital technology, and educational inequality. Through a review of existing literature and statistical data, the paper highlights the importance of inclusive educational policies and digital literacy as key factors for improving women's position in society and the labor market. Special attention is given to the need for equitable access to digital infrastructure, continuous support in education, and the creation of equal opportunities for participation in the digital economy.

Keywords: *education, digital era, gender inequality, economic gap, women empowerment.*

Introduction

Digital technology and education are important tools in today's society for lowering gender and economic disparities. Nonetheless, notable inequalities persist despite worldwide advancements in educational access, especially when considering the digital divide, which disproportionately impacts women and girls (Lacković and Gašparić, 2022; Moraliyska, 2023; Jović et al., 2024). These disparities further widen the economic divide by preventing them from gaining the skills they need to engage in the digital economy.

Digital technology is an essential instrument for the development of literacy and skills and has the potential to increase access to education (Gajić et al., 2020; Vučković, 2022). But basic literacy is also necessary to use digital technology, which presents another obstacle for many women and girls, particularly in rural regions where only 56% of people have internet access. Women's economic empowerment and educational prospects are restricted by their inability to access digital resources (UNESCO, 2022a). Only 35% of graduates worldwide are female in STEM (science, technology, engineering, and mathematics) professions, while only 26% are in AI and data science (AlOqaily et al., 2025). Women's economic potential are limited by this gender gap in digital skills and education, which also contributes to their underrepresentation in high-paying industries (UNESCO, 2022b).

Furthermore, just 38% of females in low-income nations complete lower secondary education, compared to 43% of boys, meaning that girls still fall behind their male counterparts in this regard. Particularly for girls from rural and marginalized groups, poverty continues to be one of the most important issues affecting their access to and completion of school (Dessy, et al., 2023; Bonfert and Wadhwa, 2024). Initiatives to bridge the digital gap and empower women via education exist in spite of these obstacles (Wadhai et al., 2024).

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Over the past century, women's economic emancipation has advanced significantly (Kakizhanova et al., 2025). In addition to actively engaging in the workforce, many women today hold leadership positions in businesses, governments, and international organizations (Dašić, 2024). Nonetheless, gender disparities—which persist in the EU and other areas-represent significant expenses and lost chances for women as well as for businesses that do not fully use the potential of women and the whole economy. Support for female entrepreneurs promotes innovation and wider access to the labor market, boosts economic growth, and has a beneficial impact on gender equality (Support for Female Entrepreneurs, 2024).

Disparities between men and women are measured by the Gender Inequality Index (GII) in three important areas: economic activity (labor force participation), empowerment, and reproductive health. A thorough picture of gender equality in a particular nation is provided by the meticulous definition of each of these aspects (Duong et al., 2025). Africa and Asia continue to have the highest rates of gender inequality in the world, with relatively high values (~0.45–0.55) despite advances, highlighting the long-standing need for structural change (Table 1).

Table 1. *Continental overview (1990–2023)*

Continent	GII in 1990	GII in 2023	Progress
Africa	~0.75	~0.55	Moderate decline
Asia	~0.70	~0.45	Significant decline
Europe	~0.45	~0.20	Strong improvement
North America	~0.50	~0.25	Moderate progress
South America	~0.65	~0.35	Moderate progress
Oceania	~0.65	~0.40	Gradual improvement

Source: UNDP (2025). *Global Gender Inequality Index (GII)*

However, this essay will concentrate on three major areas of gender inequality-income disparity, access to digital technology, and education inequality-that have long-term effects on social and economic advancement. These aspects are interrelated and serve as the foundation for comprehending women's access to information, their place in society, the job market, and chances for active engagement in the digital and economic domains.

Literature Review

The current academic community is interested in gender disparity in education and how it relates to digital change. The research by Ovacik (2025) examines how voice assistants and other digital technologies might unintentionally reinforce gender inequality by reproducing gender stereotypes through their functioning and design. The author highlights that women's participation in the creation of digital tools and their digital education might be a crucial way to dismantle current hierarchies and promote equality in the digital age, based on study done in Istanbul among highly educated respondents. It also emphasizes the necessity of laws that support gender parity in the IT industry.

Pereira Souza and colleagues (2025), who study the experiences of female students in Brazilian computer and communication technology schools, tackle a related problem. The authors note that the lower presence of women in technical sciences is a result of a number of ongoing obstacles in higher education, ranging from subtle forms of discrimination to feelings of loneliness and a lack of role models. According to their findings, even in technologically sophisticated environments, gender parity in STEM subjects will not be achievable until a safe and encouraging learning environment is established. However, Guo, Chen, and Zeng (2024) shed light on how digital finance may be used to support women's economic empowerment. Analyzing data from China, the authors conclude that digital financial services provide women, especially those from vulnerable social groups, greater access to capital and greater bargaining power in the labor market. This indirectly reduces the gender pay gap and strengthens women's economic autonomy, pointing to a strong link between the digital environment, education, and the reduction of gender inequality.

The economic gender gap may be closed in large part by education combined with gender-sensitive policies and digital technologies (Dašić et al., 2024a; Lunić, and Penezić, 2024). But technology advance-

ments by themselves are insufficient; careful institutional support and a more comprehensive shift in society with regard to gender norms and educational practices are also necessary (Galindo and Rojas, 2025).

According to recent research, digital inequality is a pervasive issue that disproportionately impacts women and disadvantaged groups, rather than being a technical problem with regard to device or internet access (Vuković et al., 2023; Dašić, 2023). Even when they have equal access, women utilize generative AI much less frequently than males, according to Otis and colleagues' (2024) analysis of data from 18 research. The gender gap in technology continues to exist in the absence of empowerment and focused interventions, highlighting the need for policies that go beyond merely delivering technology. Disparities in digital knowledge and abilities are influenced by attitudes toward technology and availability to ICT resources (Campos and Scherer, 2024).

The research by Miah (2024) supports this, pointing out that children from minority and lower-income families do worse academically because they have less access to digital resources and less opportunity to learn digital skills. Real inclusion requires both the capacity to utilize technology and the ability to overcome qualitative barriers, even though access to it may be a positive step. Products like mobile phones and internet access boost women's labor market involvement, according to the UNDP/ICRIER (2025) report from India. However, constraints such as gender norms, physical distance, and a lack of digital literacy still exist. The report also highlights the need for gender-sensitive infrastructure and educational policies to be directly related to digital inclusion.

In their analysis of 32 low- and lower-middle-income nations, which account for more than 70% of their total GDP, Rodríguez Pulgarín and Woodhouse (2021) employ ITU models to calculate the losses resulting from the gender gap in internet access. According to the findings, this disparity decreased their GDP by $126 billion in 2020 alone, and if the government does nothing, the total loss by 2025 would be $1.5 trillion. The authors suggest the REACT framework, which consists of rights, education, access, content, and objectives, as a comprehensive approach to empowering women and closing the digital divide via public policy and education. In addition to improving gender equality, investments in women's digital inclusion would have a major positive economic impact. The authors urge governments to recognize this opportunity and implement policies that provide women with equal access to digital technologies. As a result, digital accessibility by itself is insufficient; in addition to physical access, digital skills investment, gender sensitivity, and locally tailored access are required. The digital realm runs the danger of exacerbating rather than decreasing current disparities in the absence of more extensive educational and social assistance (World Bank, 2023).

In terms of economic disparity, according to Peck and Smith (2025), women in the United States made just 83 cents for every $1 earned by males in 2023, which is only a three-cent improvement over the previous 20 years. The authors stress that structural hurdles, such as unequal organizational structures and restricted possibilities for development, are the primary causes of the pay gap's delayed closure. IWPR's Boushey (2024) supports this image, indicating a widening disparity: women's average wages were only 82.7 cents for every dollar earned by males, suggesting that it may take decades to attain complete pay equality. This conclusion highlights the urgent need for more active public policy interventions.

According to a McKinsey research by Madgavkar and colleagues (2025), up to 80% of the wage disparity may be attributed to career milestones including flexible work schedules, parental leave, and lower pay. The authors emphasize that women's long-term career and financial success are significantly impacted by the institutional framework and employment policies. Through a thorough comparative analysis of executive salaries across 31 nations, Burns and colleagues (2025) demonstrate that up to 95% of the wage gap among executive-level employees can be explained by historical and cultural patterns, such as religious dogma, acceptance of gender inequality, and violence against women. This unequivocally demonstrates that the gender gap has both cultural and economic roots, bolstering the argument that addressing it requires tackling deeply ingrained social systems (Dašić et al., 2024b). The authors also stress that institutional compensation measures, such women quotas on boards and paternity leave legislation, have demonstrated notable results in closing the gap, but only when put into place in the context of a larger social revolution.

There are some outliers, such as Ert and colleagues' (2024) findings showing female Airbnb hosts surprisingly make more money on average than their male counterparts. Despite the apparent promise, the authors caution about selection effects, pointing out that women tend to pick more appealing listings or better portray their offerings, which might obscure persistent systemic disparities. They contend that without well-designed profiles and services, this "earnings reversal" would not be feasible, suggesting a significant degree of result determination by individual actions as opposed to a decrease in gender disparity.

Inequality in Education

Girls currently get greater levels of education than ever before, demonstrating that mankind has advanced significantly in the area of education over the past 50 years, according to World Bank data. Even while these developments are unquestionably significant, gender equality in education has not yet been entirely attained, particularly in light of the ongoing regional differences. The lower secondary school completion rate, or the completion of basic education through the eighth grade, when pupils are normally between the ages of 13 and 14, is one metric used to evaluate gender disparity in the educational system. Gender gaps in certain countries are significant, according to an examination of the most recent data available for 169 nations and territories between 2018 and 2023 (see Figure 1).

According to Figure 1, Afghanistan had the biggest gender disparity favoring males, with lower secondary school completion rates for boys and girls in 2019 differing by -30.4 percentage points. Other nations with lower completion rates for females include the Democratic Republic of the Congo (-12.1 p.p. in 2020), Iceland (-5.2 p.p. in 2021), Albania (-8.4 p.p. in 2023), and Mauritius (-9.8 p.p. in 2023). It's interesting to note that the data also show a reversal trend of gender disparity, with a far lower percentage of males than girls completing basic schooling. In 2023, the Cayman Islands saw the biggest gender disparity, with a 34.5 percentage point gender difference favoring females. Comparable trends were noted in Suriname (20.9 p.p. in 2021), Palau (21.1 p.p. in 2023), Sierra Leone (21.5 p.p. in 2021), and Tuvalu (29.3 p.p. in 2023) (Fleck, 2025a).

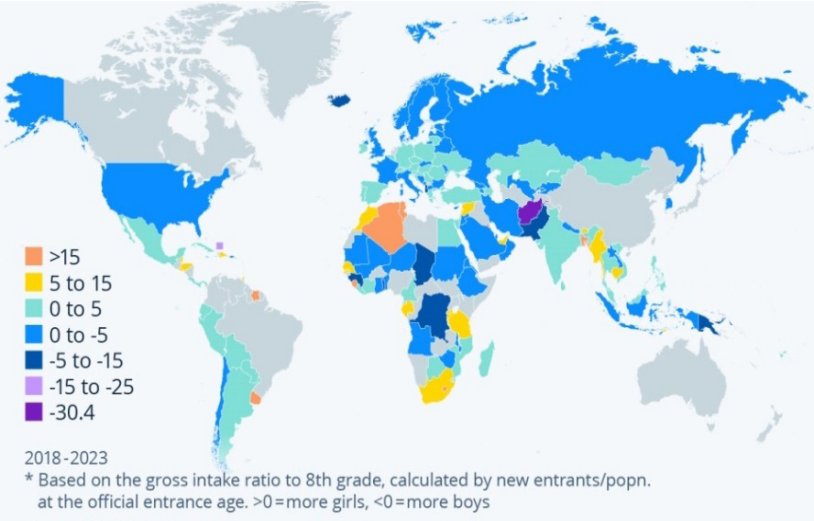

Figure 1. *Who Reaches the End of Lower Secondary School?*

Source: https://www.statista.com/chart/34070/gender-gap-between-students-completing-lower-secondary-school-education/

On the other hand, 22 nations record lower secondary school completion rates for boys and girls that are roughly equal, within a ±1 percentage point gap. Four of these nations-Hong Kong, Azerbaijan, Peru, and Turkey-achieved full gender parity in this metric.

To fully comprehend the dynamics of gender disparity, it is necessary to highlight the methodological difficulties and the temporal lag in data availability. Afghanistan is a prominent example, where no data has been documented since 2019, even though the country's well-known limitations on females' access to school were put in place after the Taliban administration returned in 2021. In order to enable prompt reactions to detrimental trends in educational equity, this situation emphasizes the critical need for more frequent and transparent data monitoring (Fleck, 2025a).

Low-income nations continue to lag behind in terms of giving girls equal access to school, despite notable advancements achieved by lower-middle-income nations. Compared to 43% of males, just 38% of girls in low-income, primarily African nations had finished lower secondary education as of 2021. This indicates that there were only 0.89 females for every boy who finished basic school.

In the mid-1980s, the gender disparity in schooling was around 0.65 girls for every boy in low- and lower-middle-income countries, including Nigeria, Kenya, Egypt, Vietnam, India, and others, according to World Bank data. Nonetheless, this ratio gradually improved and attained parity in the early 2010s. This

equalization took place as early as 2004 in upper-middle-income countries, including China, Indonesia, South Africa, Turkey, and the majority of Latin American countries (Buchholz, 2025).

In 2023, about 88–89% of children of the right age finished primary education worldwide, with girls continuing to be disproportionately represented among those who never went to school. About 75% of both genders' children finished lower secondary school in that same year. The biggest disparity was once again shown in Afghanistan, where boys were more than 30 percentage points more likely than girls to complete eight years of education.

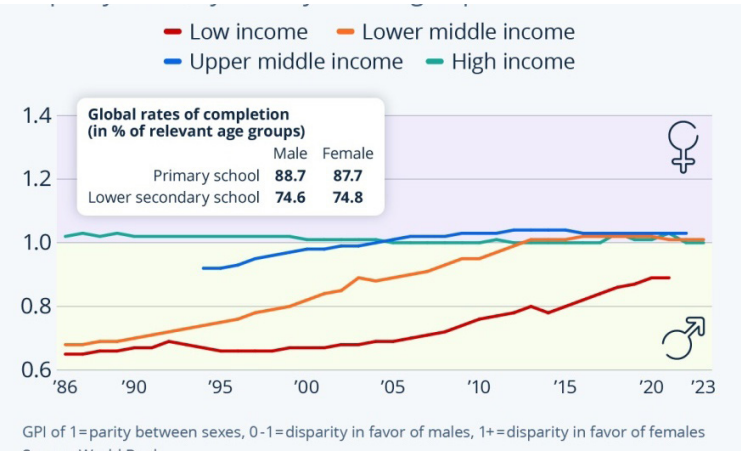

Figure 2. *Education Gender Gap Persists in Low Income Nations*

Source: https://www.statista.com/chart/34065/lower-secondary-school-completion-rate-gender-parity-index/

A gender gap still exists in the great majority of nations, albeit to differing degrees, despite ongoing attempts to increase the participation of women in STEM (science, technology, engineering, and mathematics) education. UNESCO keeps track of how many students are enrolled in STEM programs in higher education, which includes universities and vocational training. The Gender Parity Index (GPI), which has been used by the organization to examine this data, shows full gender parity at a score of 1, male advantage at a score between 0 and 1, and female advantage at a score above 1 (Fleck, 2025b).

Among the few nations where the proportion of women finishing STEM programs in higher education was equal to or even somewhat greater than the proportion of males are Turkey (2022) and Mauritania (2020, whose data is not included in the figure). The overall pattern indicates that the female-to-male ratios in STEM are generally lower in European nations; for instance, Germany recorded an index of 0.37, the UK 0.37, and Norway 0.32. However, a number of Asian nations had comparatively superior results (see Figure 3).

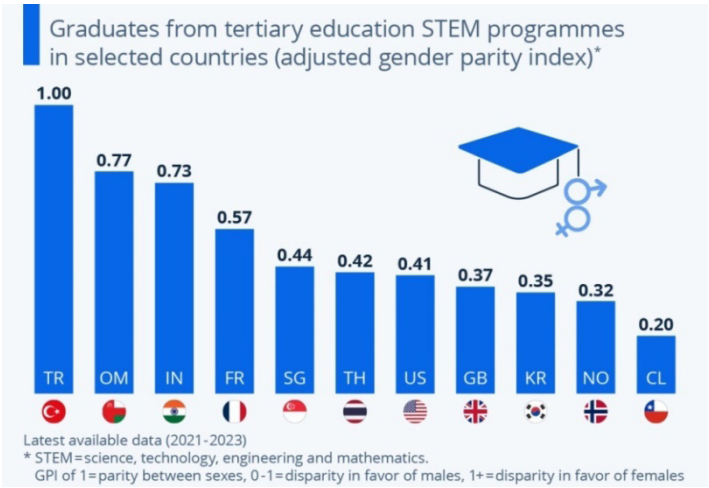

Figure 3. *The STEM Gender Gap in Education*

Source: https://www.statista.com/chart/34070/gender-gap-between-students-completing-lower-secondary-school-education/

Inequality in Access to Digital Technologies

One major worldwide issue is still gender disparity in access to digital technology. In addition to internet access, the digital divide is also evident in the degree of digital literacy, with women generally having lower levels of digital literacy and being underrepresented in STEM professions. Their career prospects and capacity to fully engage in the contemporary digital society are both impacted by this discrepancy (Dašić, G., 2023).

Compared to males, women who play video games have often been viewed as a minority since the 1990s. Although this is still mostly the case for gamers on PCs and consoles, the number of female gamers has been increasing significantly in several nations worldwide.

According to Statista Consumer Insights data, women in nations like Brazil, China, and India are particularly fond of PC and desktop gaming. That being said, women in the United States and the United Kingdom preferred console gaming. On average, 28% of female respondents in the 21 nations the survey examined stated they routinely play on computers, compared to 22% who claimed they do the same with consoles (Fleck, 2025c).

In the US, 64 percent of women and 58 percent of men reported routinely playing games on their cellphones, making mobile gaming particularly noteworthy in terms of gender dynamics. There are noticeable variations in terms of preferred genres. In 2024, casual games (reported by 39% of U.S. respondents), strategy games (34%), and action games (31%), were the three most popular game genres among women. The three most popular genres among American males were shooters (38 percent), action-adventure (45 percent), and action games (48 percent).

With 46% of respondents saying they frequently play on desktop PCs, Brazil had the highest percentage of PC gaming among the 21 nations studied overall. However, Mexico dominated the console gaming market, with 40% of respondents selecting that platform (see Figure 3).

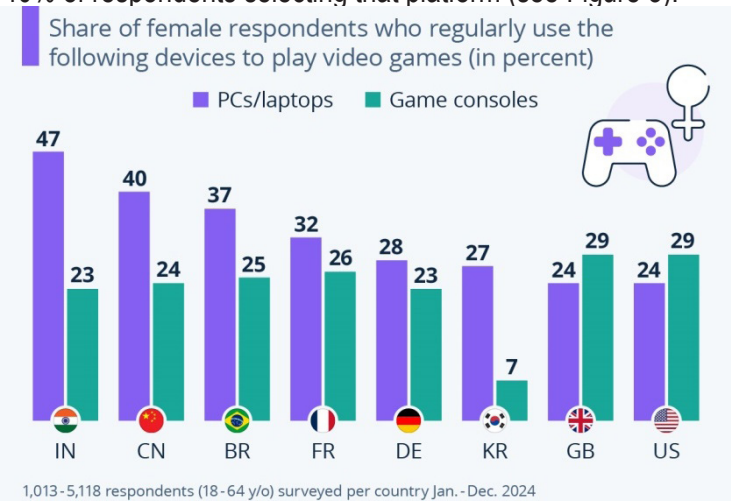

Figure 3. *State of Play: Female Gamers Around the World*

Source**:** https://www.statista.com/chart/34067/femal-pc-and-console-gamers/

According to a research by May et al. (2019), the average woman had around half as many reputation points as the average guy on one of the most widely used IT platforms. This disparity is explained by the fact that, even when variables like membership duration and activity level are taken into consideration, women are more likely to ask questions and give fewer answers, which leads to less acknowledgment for their efforts. Antonio I. Tuffley (2014) also highlighted that women's participation rates in digital technologies are much lower than men's in developing nations, contending that for women to fully benefit from digital inclusion, technological access must be accompanied by social and political change.

Gender Pay Gap

On September 18, the United Nations observes International Equal Pay Day to draw attention to the continuous efforts to provide equal compensation for labor of equal worth. No nation has fully eliminated the gender wage gap despite these initiatives and advancements in women's employment. Around

the world, women still make around 80 cents for every dollar made by males.

The pay disparity still exists even in nations like the US, where women are now more likely than males to complete college. Ironically, at higher educational levels, this disparity widens even more. The Economic Policy Institute (EPI) examined data from the U.S. Bureau of Labor Statistics and found that the gender wage gap was around 30 percent for Americans with a college degree or above and 20.3% for those without a high school education (see Figure 4).

According to EPI, women make, on average, $4.50 less per hour than males do, even just after graduation (Richter, 2023). Transparency in salaries, legally mandated minimum wages, and bolstering employees' ability to collectively bargain for more compensation are important components in bridging this gap. However, the equitable division of household duties and family care between men and women is as crucial.

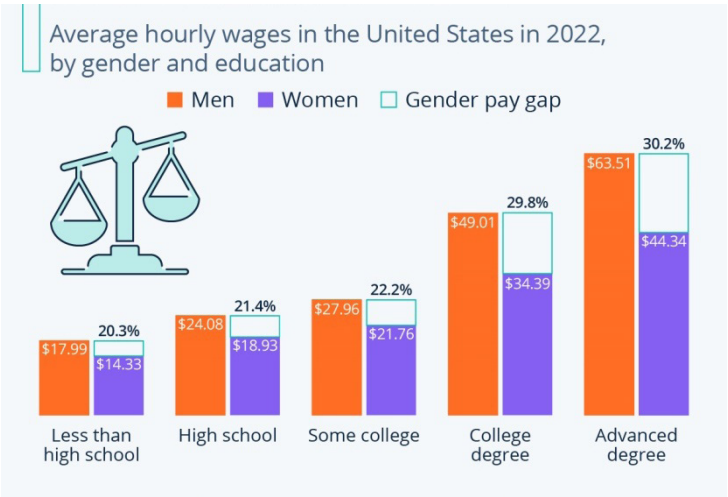

Figure 4. *Gender Pay Gap Widens With Education Levels*

Source: https://www.statista.com/chart/30852/gender-pay-gap-in-the-us-by-education-level/

For instance, when compared to the prize money given to men's teams, major event prize money still falls well short. Even if the prize pool grew from $30 million in 2019 to $110 million in 2023, as seen in Figure 5, there is still a significant gender gap in rewards. Additionally, it is noteworthy that there were 32 participating teams in 2023, up from 24 in 2019 (Armstrong, 2023).

Although there is improvement, the United States provides a noteworthy illustration of how national football associations might momentarily close this gap. A "historic" arrangement was made there last year, wherein the U.S. Soccer Federation agreed to divide the entire prize money evenly between the men's and women's national teams in events in which both compete (Pijetlović, 2024).

Figure 5. *The World Cup Gender Pay Gap SOCCER*

Source: https://www.statista.com/chart/27871/soccer-football-gender-gap-prize-money/

Conclusion

It is evident that digital transformation might have conflicting consequences on gender equality given the growing integration of digital technology into every aspect of contemporary life. On the one hand, women's economic empowerment is made possible by digital banking, electronic platforms, and online labor marketplaces, particularly in situations when conventional restrictions still exist in the real world. According to some research, women who actively use digital tools and platforms can outperform males in some fields, including the gig economy or some types of entrepreneurship, and even earn comparable wages.

This beneficial dynamic is not ubiquitous, though. Digital technologies have the potential to replicate or even exacerbate gender inequality if they are not properly planned for and managed. As evidenced by gendered norms that influence how and why technology is used, algorithmic prejudice, and restricted access to digital resources, technological growth does not always translate into greater equality. Furthermore, even among the most educated members of society, there is still a gender wage difference, and economic outcomes are significantly shaped by factors including informal labor, caregiving duties, and institutional support.

Therefore, it is important to see digitalization as a socially conditioned phenomena that necessitates active involvement in labor, technology, and educational policy rather than as a neutral process. Combining access to education, empowerment via digital skills, algorithmic transparency, and the redistribution of unpaid care labor is crucial if the digital world is to become a place of inclusion rather than increasing division. Then, instead of being a band-aid or selected solution, the digital economy may actually be used to reduce the gender income divide.

Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization: D.D.; methodology: D.D.; resources: M.I.K; G.K. and G.J., supervision: D.D.; writing—original draft preparation: D.D.; writing—review and editing: D.D. All authors have read and agreed to the published version of the manuscript.

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Personalized Learning through Artificial Intelligence: Opportunities, Risks, and Policy Perspectives

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Abstract: Artificial Intelligence (AI) is redefining the landscape of personalized education by enabling adaptive systems that respond dynamically to individual learning needs. This paper explores how AI technologies-including machine learning, big data analytics, and intelligent tutoring systems-support the transformation of pedagogical models. Key opportunities discussed include real-time personalization of content delivery, increased student motivation, and inclusive learning environments. At the same time, the study critically examines potential risks, such as data privacy concerns, algorithmic bias, and the erosion of human-centered pedagogy. Policy implications are addressed with recommendations for regulatory frameworks to ensure ethical and responsible AI integration into education. The paper emphasizes the need for empirical research to validate AI-driven models in diverse educational settings. By aligning technological innovation with humanistic values, the paper contributes to ongoing discourse on how AI can support-not supplant-the role of educators. The findings provide a foundation for future research and policy design aimed at creating equitable, transparent, and effective personalized learning ecosystems.

Keywords: *artificial intelligence, personalized learning, educational policy, algorithmic ethics, adaptive learning systems.*

AI and the Future of Personalized Learning

It is widely acknowledged that artificial intelligence is a primary driver of innovation. We are witnessing the daily use of artificial intelligence and its tools in all spheres of human life. Artificial intelligence is closely related to machine learning. Artificial intelligence refers to machines replicating human cognitive characteristics, and artificial intelligence can give many recommendations both for improving learning and for preparing educational material. Scientists argue that artificial intelligence should enable machines to replicate human cognitive abilities, but at the same time there is a strong view that artificial intelligence should never attempt to take over the entirety of human multi-layered mental processes (Filipović, Bjelajac, Merdović, and Stošić, 2023). Because machines can collect, track, and analyze so much data about people, it is very possible for those machines to use that information against humans. Any powerful technology can be misused (Bjelajac, Filipović, and Stošić, 2022, p. 359). Contrary to AI, machine learning implies that machines learn from the information they are given and access, thereby improving their performance (Duckett, 2010). Unlike artificial intelligence, machine learning enables the development of educational systems that can adapt themselves according to the information they receive and that dynamically change in accordance with the progress of students. From an educational perspective, numerous AI tools have greatly helped to personalize learning and thus change the way education is approached (AlOqaily, Qawasmeh, and Tawalbeh, 2025). When we talk about education, the eternal problem has been the quality of teaching that is provided to different categories of children. If the teaching criteria are

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raised, the weaker ones will diminish even more knowledge. If the criterion is lowered, then children with advanced knowledge will remain in further progress. It is precisely in this gap that artificial intelligence can make a contribution. In relation to the needs of individuals, the artificial intelligence can determine and propose a learning plan and program for each individual and thus adapt learning itself to personalized learning. Personalized learning adapts the content, methods and pace of learning to the individual needs, interests and styles of each student. It is focused on the needs, abilities and interests of individual students. What separates personalized learning from other learning is that personalized learning focuses on the student as an active creator of their own educational experience. Students who receive content in a format that suits their learning styles report higher levels of motivation, engagement and success (Graf et al., 2009). Personalized approaches lead to greater satisfaction and more efficient learning. When talking about personalized learning, we cannot leave out artificial intelligence (AI) and machine learning, which are increasingly being integrated into the education system (Stošić and Janković, 2024). A personalized approach uses analytics tools and technologies, including artificial intelligence (AI), to continuously collect and analyze student data to adapt instructional materials and strategies in real time (Talapbayeva et al., 2024). This approach contrasts with traditional "one-size-fits-all" methods by accommodating different learning paces, preferences, and goals, allowing students to progress based on mastery, not age or grade level (Knox, 2020). Personalized learning is based on the premise that every student can succeed if they are provided with the right resources and support (Duckett, 2010).

Personalized learning has its roots in the early 1960s when the first generation of educational software (eg the PLATO system developed at the University of Illinois) enabled basic forms of adaptive learning. Already in the 1990s, with the advent of the Internet, learning management systems (LMS) appeared that allowed greater flexibility in the organization of the teaching process.

Personalized learning experienced a real rising in the 21st century with the development of artificial intelligence (AI), learning analytics and big data technologies. Certainly, digitalization supported by artificial intelligence has transformed education itself, making it far more accessible, efficient and attractive to every individual. Due to the mass use, the lack of professional staff, the question of ethics, the bias of algorithms and even privacy itself is raised.

An overview of the modern application of AI in personalized learning

When we talk about the application of AI tools in personalized learning, we primarily mean adaptive tutors, intelligent tutors and recommendation systems. Based on insights from AI systems, teachers can create differentiated lesson plans. These tools represent the foundation of modern AI applications in education and support personalization, self-directed learning and improved student evaluation (Duong et al., 2025). AI systems provide immediate feedback on accuracy and understanding, thereby speeding up the learning and correction process. AI can adjust the order of teaching units – eg. a student with an auditory style will be offered more video lessons and dictated explanations, while visual learners will be offered infographics, maps and animations. The authors emphasize that AI in education can enhance educational experiences by making learning more personalized, flexible, and engaging, without replacing teachers but rather augmenting their capabilities (Duong et al., 2025). AI tools offer analytics on student progress and difficulties, helping teachers plan interventions more precisely (Holmes et al., 2019). AI tools allow students to learn at their own pace. This adaptability helps students overcome frustration caused by content that is too difficult or too easy, thereby increasing their sense of competence – an important factor in internal motivation (Deci and Ryan, 2000). AI tools enable students with specific disabilities to master the material more easily through the use of assistive technologies and adapted educational paths, which contributes to more equal education and greater motivation.

Adaptive tutors use artificial intelligence to adapt content to an individual's learning in real time. In addition to a personalized experience, adaptive tutors can also provide students with an interactive learning experience. Adaptive tutors are web-based interactive teaching systems that evolved from intelligent teaching systems (Kamardeen 2014; Khawaja, Chen, and Marcus 2014). Their goal is to personalize the educational process to suit each individual's pace and learning style, rather than relying on traditional methods of learning. Student evaluations indicate that students prefer the computer-based approach over the traditional approach (Nirmalakhandan, 2007). The same author argues that based on students' performance on two types of paper-based tests he conducted, he believes that computerized adaptive

tutorials can be a valid tool in assessing their problem-solving skills. In contrast to students, adaptive tutorials provide educators with the ability to easily monitor and analyze student interactions with the tutorial. Examples of adaptive tutorials include the Knewton and DreamBox Learning platforms. What all platforms have in common is that they provide an environment where students can work at their own pace, at a time and place that suits them. Incorporating adaptive tutorials that include a combination of guided practice, interactive opportunities and immediate, adaptive feedback provides students with learning opportunities that can improve their confidence, understanding and learning outcomes (Weltman, 2025).

Intelligent tutors (ITS - Intelligent Tutoring Systems) simulate the work of a human teacher. They not only track student responses, but also model their knowledge, detect faulty thinking, and offer feedback aimed at correcting specific cognitive errors. In the beginning, there all talk about teaching with the computer assistance. Today, that same computer-assisted instruction has evolved into Intelligent Instructional Systems (ITS). Intelligent tutors provide real-time feedback, indicating not only the correctness of answers but also the causes of errors. Such support develops metacognitive skills and encourages students to reflect on their own knowledge, which contributes to academic success (VanLehn, 2011). ITS systems often use complex learner models and techniques from artificial intelligence, such as expert systems or machine learning (Suresh, Kolluru, and Ubaidullah, 2025). Examples are AutoTutor and Cognitive Tutor.

With the increasing development of ICT and their use in education, the problem of large amounts of information has arisen. This large amount is reflected in the time that authors spend searching for useful information and extracting the necessary and requested information. It is precisely because of these problems that recommender systems have emerged to solve these problems. Recommender systems in education work in such a way as to provide recommendations for teaching resources, courses or tasks. Recommender systems have become a very commonly used tool in various fields such as e-commerce, social networks, digital media and books (Nadine, Cao and Deng, 2016), as well as in the field of education, in teaching and academic advisory services (Deschênes, 2020). Recommender systems are software tools that assist users in the decision-making process by applying information filtering, data mining, and predictive algorithms (Venkatraman, 2017). Based on previous activities, interests, or knowledge level, the system analyzes the data and recommends the next steps in learning. The recommender system can be very useful for students when choosing elective courses (Dwivedi and Roshni, 2017). Burke (Burke, 2007) differentiate six different classes of recommendation approaches: collaborative filtering (CF), content-based filtering (CBF), knowledge-based filtering, context-based filtering, demographic filtering, and hybrid filtering. Typical representatives of recommender systems in education are e-learning platforms Coursera, Edmodo, or Duolingo. Coursera, for example, uses AI to personalize the educational experience. It offers adaptive course recommendations based on the user's previous interests, knowledge level and goals. AI is used to automatically evaluate assignments, generate feedback, and automatically transcribe lectures. The platform collaborates with universities and companies, enabling massive open education (MOOC). Coursera certainly helps teachers to assess and analyze student performance more quickly. A similar platform is Duolingo, which uses intelligent tutors and adaptive teaching algorithms. Platforms like Duolingo use game elements (points, levels, challenges) to encourage motivation. Studies show that such approaches significantly increase student engagement and frequency of use of educational resources (Vesselinov and Grego, 2012). The system uses gamification, natural language processing (NLP) and machine learning to adjust the difficulty of tasks, recognize student weaknesses and offer exercises that strengthen specific skills. Using gamified and interactive systems like Duolingo increases engagement and regular learning (Loewen et al., 2020). On the other hand, Chinese education platform Squirrel AI uses advanced intelligent teaching systems that break down skills and concepts into the smallest possible units to accurately detect knowledge gaps.

By type of education, recommender systems cover mainly formal education, especially student-oriented (Urdaneta-Ponte et al., 2021). AI tools such as adaptive and intelligent tutors adapt the learning content to the individual needs, pace and style of the learner (Luckin et al., 2016). All these platforms enable learning without time and space limitations, which is especially important for students with specific needs or from remote areas.

Learning support for students with special needs Human-Centered AI for Inclusive Education

AI tools significantly contribute to inclusive education, especially when it comes to students with special educational needs. By using artificial intelligence-based technology, it is possible to provide personalized support, assistive functions and an environment that allows each student to progress according to their abilities. AI systems can automatically adjust task complexity, presentation speed, and content modality (text, audio, video) according to the abilities of students with learning disabilities, autism, or ADHD (Attention-deficit/hyperactivity disorder). Adaptive tutors enable learning without pressure and at a safe pace (Al-Azawei et al., 2017). Tools for converting speech into text (speech-to-text) and vice versa, image and voice recognition, as well as automatic transcription allow students with visual, hearing or motor disabilities to participate equally in classes. Systems such as Microsoft Immersive Reader or Seeing AI use NLP and visual recognition for this purpose. AI can recognize signs of frustration, inattention or cognitive overload by analyzing facial expressions, body language or behavior (affective computing). This enables timely intervention and additional help for students who have difficulties in emotional regulation. AI enables detailed assessment of student progress, identifies areas of weakness and recommends specific interventions. This is especially useful for students with intellectual disabilities, as it requires clearly structured and goal-oriented teaching.

Risks and challenges of applying AI in personalized learning

Ethics and protection of student data privacy are key challenges in the application of artificial intelligence (AI) in education. While AI tools offer numerous advantages, their use must be aligned with data protection laws and ethical principles that protect learners, especially children and vulnerable groups. AI systems collect large amounts of students' personal data: names, behavioral patterns, scores, and even emotional reactions. Unethical use of this data – without consent or a clear purpose – can lead to violations of student privacy and security (Williamson and Eynon, 2020). Lawmaking that emphasize accountability, transparency in AI, mitigating bias, and comprehensive application of ethical principles is an effective strategy for dealing with "dark AI" (Bjelajac, Filipović, and Stošić, 2023, p. 530). Legal frameworks such as GDPR (EU) and FERPA (US) require explicit informed consent from parents and students for data collection and processing. Ethics dictate that educational institutions clearly communicate why data is collected, how it is used and who has access (Regan and Jesse, 2019). AI models can be biased if they are trained on unrepresentative data, which can lead to unfair educational recommendations, grading or labeling of students. Ethics requires regular testing and transparency of algorithms to ensure fairness. Ethics mandates the limitation of covert forms of monitoring and the use of only those technologies that directly contribute to the educational goal.

Algorithmic biases pose serious ethical challenges in the application of artificial intelligence (AI) in education. These problems occur when algorithms make decisions that are unfair, discriminatory, or based on non-objective patterns in the data. Bias occurs when the training data is incomplete, historically biased, or unrepresentative. For example, if an AI system learns from data that favors certain demographic groups (eg, students from urban areas), the resulting recommendations may be unfair to students from other areas (Noble, 2018). AI systems can classify students according to past performance, behavior, or demographic characteristics, creating a risk of labeling (eg, "bad students," "low-risk students") that can affect the treatment they receive and teacher expectations. This type of prediction can self-confirm negative educational outcomes (O'Neil, 2017). Algorithms that recommend educational content or ways of learning may ignore cultural, linguistic or cognitive differences. If students of different genders, languages or ethnic groups are not offered diverse content, educational inequalities may be reproduced. In order to mitigate bias, it is necessary to use diverse and representative data sets, conduct regular audits of algorithms, involve ethical committees in the development of AI systems, increase transparency in the way recommendations or decisions are made (Binns, 2018).

The danger of automation and depersonalization of education is becoming more pronounced with the increase in the application of artificial intelligence (AI) in educational systems. Although AI offers numerous advantages, an over-reliance on automated processes can compromise the core pedagogical values and humane aspects of teaching. Personal contact between teacher and student plays a key role in education - not only in the transfer of knowledge, but also in the development of empathy, support and motivation. Automated tutors and evaluators cannot adequately replace the emotional intelligence and

ethical judgment of teachers (Selwyn, 2019). AI systems often operate according to predefined patterns and metrics, which can lead to a standardized approach to learning. This approach ignores contextual, cultural and individual factors, reducing the quality and relevance of education (Knox, 2020).

Policy and Regulatory Perspectives on AI in Education

Aware of the shortcomings and threats we face, it is certainly necessary to set clear ethical guidelines. In general, national and institutional codes of ethics for the use of AI in education should be clearly formulated. "The incorporation of artificial intelligence in education has enormous potential to transform the educational process, providing benefits such as increased productivity and tailored teaching" (Stošić and Janković, 2023, p. 68). It's not enough to just use AI tools. It is necessary to ensure that AI tools consider the rights of students, with a special emphasis on privacy protection, consent and transparency. The use of AI for mass surveillance or profiling of students without control should definitely be banned.

UNESCO's first global standard on the ethics of artificial intelligence – the "Recommendation on the Ethics of Artificial Intelligence", adopted in 2021 and applicable to all 194 UNESCO member states (https://www.unesco.org/en/articles/recommendation-ethics-artificial-intelligence). The recommendation clearly states that tools should be developed to help member states build a comprehensive picture of how prepared they are to ethically and responsibly deploy AI for their citizens. The Global Observatory on Ethics and Governance of Artificial Intelligence aims to provide a global resource for policymakers, regulators, academics, the private sector and civil society to find solutions to the most pressing challenges posed by AI (https://www.unesco.org/en/artificial-intelligence/recommendation-ethics).

Regardless of social and geographic origin, fair access and digital inclusion should be ensured where educational policies include strategies to reduce the digital gap. All students, regardless of gender equality, should have access to devices and the Internet. More attention should be given to the development of an AI strategy aimed at rural and marginalized communities.

Teachers should definitely be trained in the critical use of AI tools and not just in their use. Teachers themselves must be involved in the decision-making and training process. We should strive to introduce a professional development program that includes digital pedagogy and AI ethics. Educators need to understand how AI can affect the education system as well as understand where this technology is going with its progress. Teachers must know and understand where AI can replace humans and where it can only complement and help them. We must constantly point out the dangers that really exist, and work permanently on this aspect of mental health of individuals, nations, and global society (Bjelajac, Filipović, and Stošić, 2022).

Standardizing the use of AI in schools and universities

Standardizing the use of artificial intelligence (AI) in schools and universities is a key step towards ensuring the quality, fair and ethical application of technology in educational systems. The goal of standardization is to establish common guidelines, technical frameworks and pedagogical principles for the integration of AI into the educational process. Ministries of education and educational institutions should define official guidelines for the use of AI tools, including criteria for their accreditation, security and compliance with pedagogical goals. It is necessary to standardize procedures for the selection, evaluation and updating of AI systems, in cooperation with regulatory bodies and experts in education and ethics. The Ethical Guidelines for Artificial Intelligence in Education of the Ministry of Education of China outlines principles for ensuring the responsible use of artificial intelligence technologies in educational institutions (Wei and Niemi, 2023). China has developed the National Guidelines for the Ethical Use of AI in Education (2021), while the EU is laying the groundwork for responsible use through the Ethical Guidelines for Trustworthy AI. Primary school children in China are prohibited from using AI tools that generate open-source content as their own, while educators must ensure that AI can complement, but not replace, human-led teaching (https://m.chinanews.com/wap/detail/ecnszw/hernfey9438915.shtml). According to these guidelines, students are not allowed to independently use open source AI-based generators. In contrast, secondary school students can use and explore AI-generated content. Parents are advised to monitor how their children use artificial intelligence and to protect their personal data. They are urged to teach their children not to rely on technology alone but to prioritize emotional engagement. China's Ministry of Education has issued ethical guidelines that emphasize principles such as fairness, transparency and accountability.

All these guidelines and regulations directly mandate that the law on data privacy be strictly followed, thus ensuring the protection of the data of the students themselves. Educational institutions themselves must provide security measures to ensure a measure of protection of personal data. Schools are preparing their children for future labor markets by increasing digital literacy by implementing artificial intelligence technologies in the curriculum. The implementation of AI technology alone is not enough for progress, but schools are obliged to monitor the application of artificial intelligence and its impact on learning outcomes. All educators must receive training on the effective use of artificial intelligence. The government is working with technology companies to develop artificial intelligence solutions that meet educational needs while adhering to ethical standards. China's approach to regulating AI in education focuses on balancing innovation with ethical considerations, aiming to improve educational outcomes while protecting the rights and well-being of students. Important themes include inclusion, personalization, justice, safety, transparency, and responsibility, which serve as the foundation for developing AI in education.

AI tools must certainly be aligned with national curricula and exam standards. Standardization must include pedagogical performance indicators, to give insight into whether the AI tool contributes to the development of students' knowledge, skills, engagement and critical thinking. It is necessary to introduce quality indicators such as precision of recommendations, adaptation time and level of personalization. A standardized framework must include mandatory protection of student privacy, as well as guidelines for algorithm transparency and the possibility of human intervention.

Future Directions and Research Recommendations

In modern education, the need for training teachers and educators to work with artificial intelligence tools is becoming increasingly evident. The introduction of artificial intelligence in schools and universities requires not only technical integration, but also the development of digital and pedagogical competences among teaching staff. Educators must understand how AI works, what its capabilities and limitations are, and how it affects learning, assessment, and interaction processes. This includes a basic understanding of algorithms, personalization, learning analytics and ethical implications (Zawacki-Richter et al., 2019). Training should not focus exclusively on technical skills, but also on the pedagogical integration of AI: how to use adaptive tutors, recommendation systems or evaluation tools for the purpose of differentiated and inclusive teaching. Educators must be trained to understand the legal and ethical aspects of using AI tools, especially in relation to the protection of student privacy, consent and transparency of algorithms. Training should also include recognition of biases and automated decision-making problems. Given the rapid evolution of AI technologies, teacher training must be continuous, with self-study resources, seminars and accredited courses available. Institutional support through strategies for the digital transformation of the educational system is also needed.

In general, the application of AI in education has a pedagogical value. On the one hand, there is personalization, adaptive learning, real-time learning support versus depersonalization, reducing student-teacher interactions. With the application of modern technologies, we have automated assessment, time saving, scalability. The use of technologies also has its drawbacks, namely technical errors, dependence on platforms, low interoperability. AI tools in education certainly provide progress, but one should definitely take care of discrimination, stereotyping, unauthorized data collection, surveillance, algorithmic bias... As for algorithmic bias, its impact in the context of differences between genders, ethnic groups and students with developmental disabilities has not been sufficiently investigated (Holmes et al., 2022). AI tools provide support in evaluation but reduce the pedagogical autonomy of teachers.

Conclusion

AI in education represents a significant step towards personalization and more effective learning. Through timely support, motivational strategies and analytical insights, these tools help increase both academic success and intrinsic student motivation. Automatic detection of learning styles through AI analytics is a key step towards creating an intelligent, adaptive education system that does not treat all students equally, but in accordance with their cognitive profiles. Students with special needs are given tools that allow them to achieve their full potential much more easily.

Every phase of the development and implementation of AI tools in education should have integrated ethics and privacy protection. Policies need to be in place that ensure safety, fairness, and student autonomy in the digital environment. Policies need to strike a balance between innovation and accountability. As much as AI can improve teaching itself, it is more important to preserve the human element of teaching. The teacher is the main who should lead and control the teaching process and not to be replaced by technology. Technology and pedagogy must support each other. The standardization of AI in education must be multidimensional – technical, pedagogical, and ethical. Without teacher training, AI cannot be properly used and exploited. Teachers must be motivated and properly guided in using AI and its tools in teaching in order to derive the benefits of using it. Without proper training, the use of artificial intelligence itself will be reduced to only the initial form of searching and using information.

Future research should move beyond the development of technical functionalities and focus on several key directions:

- **Longitudinal studies** on the actual impact of AI-supported personalization on student performance, engagement, and motivation in diverse educational contexts.
- **Critical analysis of algorithmic decision-making** to examine fairness and bias in adaptive learning environments, especially among students of different socio-economic backgrounds, ethnicities, or learning abilities.
- **Evaluation of teacher-AI interaction models**, including how AI tools influence teacher autonomy, pedagogical strategies, and classroom dynamics.
- **Exploration of students' perceptions and emotional responses** to AI-mediated learning, particularly in terms of trust, agency, and well-being.
- **Policy-oriented research** aimed at developing governance frameworks that regulate the ethical design, deployment, and accountability of AI in education, with special attention to low-resource settings.

Implications for Future Research

Regardless of the positive effects and applications of artificial intelligence in education, far-reaching research is certainly needed to have a true picture of the application of artificial intelligence in education. The research itself should not encompass the technical capabilities of artificial intelligence, but must encompass ethical, pedagogical and socio-cultural dimensions. Certainly, a critical and reflective approach will provide a better picture and better understanding of how artificial intelligence technology affects not only educational outcomes, but also human relationships, student activity and institutional practice.

Key directions for future research include:

- Longitudinal impact studies to assess the sustained effects of AI-based personalization on learning outcomes, engagement, and motivation across diverse educational levels and demographic groups.
- Critical analysis of algorithmic bias and transparency, particularly regarding how AI systems classify, recommend, or assess students, and how such classifications may reproduce social or educational inequalities.
- Exploration of AI-teacher collaboration models, with emphasis on how AI can augment rather than undermine teacher autonomy, pedagogical creativity, and professional judgment.
- Examination of student perspectives, focusing on trust, acceptance, resistance, and emotional responses to AI-mediated learning environments, particularly among vulnerable populations.
- Development of policy and governance frameworks that support the ethical deployment of AI in education, ensuring data protection, accountability, and inclusivity, especially in low-income and rural educational settings.

Such interdisciplinary and multi-perspective research will contribute to the development of a just, hu-

man-centered, and sustainable AI-enhanced educational ecosystem. Without addressing these broader issues, technological solutions can become mere cutting-edge interventions and attempts to transform education.

Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, L.S., A.R., formal analysis, O.K., B.B; methodology, O.M.; writing - original draft preparation, L.S.; writing - review and editing, A.R., O.K., B.B., O.M. All authors have read and agreed to the published version of the manuscript.

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The EU AI Act and Its Contractual and Educational Implications: AI, Education, and the Law of Obligations

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Abstract: The European Union's Artificial Intelligence Act (EU AI Act), adopted in 2024, and introduced the first comprehensive legal framework for regulating artificial intelligence across sectors, including education. This paper explores the dual implications of the Act—contractual and pedagogical—within the context of digital education, with a particular emphasis on IT curricula. It examines the risks of diminishing foundational knowledge in algorithmic thinking, programming, and system architecture as AI tools become more prevalent in academic settings. The paper analyzes legal obligations arising from the use of AI in education, such as transparency, informed consent, and liability, situating them within the law of obligations and contract law. It argues that AI integration in education, particularly in high-risk domains, requires more than technical compliance: it demands sustainable, ethical, and pedagogically informed implementation. Drawing on EU policies, UNESCO frameworks, and recent academic literature, the paper proposes strategic recommendations to ensure that digital education not only complies with legal standards but also upholds the core mission of higher education—critical thinking, ethical responsibility, and the cultivation of foundational knowledge.

Keywords: *EU AI act, digital education, IT curriculum, contractual obligations, AI literacy.*

Introduction

The rapid development of artificial intelligence (AI) in recent years has fundamentally transformed various sectors of society, including education. AI-based technologies are increasingly integrated into educational systems at all levels, promising personalized learning, automated evaluation, and real-time student support. While undeniably useful, these tools raise important questions about the sustainability of fundamental knowledge, especially in technical disciplines such as information technology (IT). In 2024, the European Union adopted the EU AI Act, the first comprehensive regulatory framework for the use of artificial intelligence across EU territory, with a special focus on the educational sector (European Parliament "EU AI Act: First regulation on artificial intelligence", 2024). Article 4 of this document explicitly mentions the importance of developing AI literacy among students, educators, and institutions, while also emphasizing the responsibility of educational providers to implement AI tools in a transparent and ethical manner (Artificial Intelligence Act - Article 4, n.d.). As institutions increasingly introduce tools such as ChatGPT, Copilot, GitHub Copilot, and others, one important question emerges: do students truly understand what happens "under the hood" of these tools? If students stop learning the basics of programming, algorithmic thinking, and software architecture, how will they critically use AI tools, develop new technologies, or solve complex problems? This concern is especially relevant in IT education, where a noticeable decline in student motivation to master fundamental skills has been observed (Poth, 2023).

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Today, many students use AI tools to assist with homework, coding tasks, and even writing term papers and theses. While such tools undeniably increase productivity and offer customized support, they also carry the real risk of diminishing foundational knowledge. According to research conducted by the University of Iowa, students increasingly perceive AI tools as substitutes for understanding rather than as supportive aids (University of Iowa, 2023). This creates an educational paradox: students pass courses with AI assistance, yet graduate without a deep understanding of IT principles. The same concern is echoed in the latest report by the U.S. Department of Education, which warns that "AI must serve educational goals, not redefine them" (U.S. Department of Education, 2023). Despite the growing popularity of AI tools, experts stress the importance of preserving traditional IT competencies. A piece published in Generative AI Newsroom emphasizes that foundational skills such as understanding algorithms, data structures, and object-oriented programming are not only crucial for comprehending AI systems but also for their ethical and responsible use (Caplan, 2024). Moreover, according to an analysis by the Digital Education Council, the EU AI Act categorizes education as a "high-risk" domain, meaning every implementation of AI technologies in education must be carefully evaluated and justified (Digital Education Council, 2024). This further confirms the need to maintain the core of IT as a discipline: understanding how systems work, not just how to use them.

Beyond the evident technological and pedagogical challenges, the implementation of AI systems in education raises a series of legal questions that can be approached through the lens of the law of obligations. The use of AI tools within educational institutions inherently involves the formation of contractual relationships-either explicit or implicit-between students, educators, institutions, and third-party service providers (e.g., AI platform vendors). Within this framework, issues such as informed consent, liability for harm resulting from inaccurate assessment or algorithmic bias, and the right to accurate information and fair treatment, fall directly within the scope of contract law. Although the EU AI Act is primarily a regulatory document, it indirectly shapes the structure and content of these contractual relationships by imposing obligations related to transparency, human oversight, and risk assessment. These obligations introduce a new layer of legal accountability: if an institution fails to adequately inform students about the role of AI in grading, or if it neglects to evaluate potential discriminatory outcomes of algorithmic decision-making, it may be liable not only under regulatory frameworks but also under civil law for breach of contractual duty. Consequently, the EU AI Act should not be viewed solely as a technical or compliance-oriented policy but also as a legal framework that redefines institutional obligations and user rights within digital education. Understanding this intersection is particularly important in the IT education context, where the risks of over-automation and loss of fundamental knowledge carry both pedagogical and legal implications.

The introduction of AI into digital education is particularly sensitive within the context of IT curricula. Unlike other fields, IT education is inherently structured around the understanding, development, and critical evaluation of digital systems themselves. Incorporating AI tools into these programs without reinforcing the underlying theoretical knowledge can lead to superficial skill acquisition and reduced long-term competence. There is a tangible risk that students may graduate with experience in AI-assisted workflows, but without the cognitive and technical foundations required to innovate, debug, or ethically evaluate those very systems. This makes the integration of AI in IT education not only a pedagogical challenge but also a matter of strategic importance for the future of the digital profession. Despite the growing integration of AI tools into educational practices and the increasing appeal of personalized digital solutions, educational institutions must carefully consider the long-term implications of such implementation. The EU AI Act not only classifies education as a high-risk domain but also explicitly calls for the responsible integration of AI systems in a way that preserves the integrity and quality of the educational process (European Parliament, 2024), (Digital Education Council, 2024). Within this regulatory framework, it becomes essential to emphasize that core theoretical and programming skills - such as algorithmic thinking, understanding software architecture, and basic programming literacy - cannot be replaced by automated tools, but rather constitute the foundation for their critical and ethical use. The purpose of this paper is to highlight the necessity of a balanced integration of AI in education while safeguarding space for foundational knowledge, ensuring a sustainable, quality-driven, and theoretically grounded IT curriculum aligned with current European policy frameworks.

The EU AI Act and the Education Sector

With the adoption of the EU AI Act in 2024, the European Union established the first comprehensive legal framework for the regulation of artificial intelligence across various sectors, including education. This landmark regulation is not only pioneering in scope but also in its ambition to protect fundamental rights and ensure ethical AI deployment in contexts that involve vulnerable populations, such as students and educators. The education sector has been explicitly classified as a high-risk domain due to the inherently impactful nature of decisions made through AI technologies. Automated systems used in education-ranging from student assessment tools to algorithmic selection mechanisms-can significantly influence individuals' learning trajectories, access to opportunities, and overall educational outcomes. Recognizing this, the EU AI Act mandates a transparent, safe, and ethically aligned implementation of AI systems in education. Institutions are required to exercise increased diligence when introducing AI into their pedagogical and administrative practices, particularly in areas that directly affect the rights and futures of learners. Beyond its regulatory-technological scope, the EU AI Act also invites analysis through the lens of contract law, particularly within the framework of the law of obligations. The deployment of AI systems in education gives rise to both explicit and implicit contractual relationships between educational institutions and their stakeholders-students, teachers, and third-party service providers. These relationships entail specific obligations concerning transparency, informed consent, data protection, and access to information regarding algorithmic processes. Should an institution fail to meet these standards, it may be held contractually liable for breaches such as failure to inform, data misuse, or harm resulting from algorithmic bias. In this light, the EU AI Act should not be regarded merely as a technological policy document, but rather as a multi-dimensional legal framework that redefines institutional responsibilities in a digital learning environment. It underscores the necessity of aligning digital innovation with legal accountability and ethical governance, thus safeguarding the integrity of education and the rights of its participants in the era of artificial intelligence.

Key Provisions Relevant to Education

The EU AI Act introduces a formal obligation of AI literacy for all stakeholders in the education sector, including students, teachers, administrative staff, and educational institutions. This literacy extends beyond the basic ability to operate AI tools; it encompasses an understanding of their functional capacities, technical limitations, potential risks, and broader implications for the educational process (European Commission "AI Act | Shaping Europe's digital future", 2024). The underlying premise is that users of artificial intelligence should not remain passive recipients of automated recommendations and decisions, but should instead cultivate a critical awareness of how such systems influence their learning environments. This provision is particularly significant for the field of IT education, where students are expected not only to employ AI tools in everyday tasks, but also to comprehend their internal mechanics-ranging from machine learning models to algorithmic structures and the data architectures underpinning these systems. In this context, AI literacy also implies meta-literacy: the ability to understand how and why AI systems operate in specific ways, and how they may be applied ethically and responsibly in practice. In addition, the EU AI Act requires educational institutions that adopt AI technologies to ensure the transparent and ethical use of these systems. This includes the explicit obligation to provide students with clear and accurate information about when, where, and how AI is used in educational activities-be it in course personalization, automated knowledge assessment, candidate selection, or learning analytics (European Parliament "EU AI Act: First regulation on artificial intelligence", 2023). Transparency must be sufficient to ensure that users understand which data the system processes, how decisions are made, and what consequences these decisions may have on their educational trajectory. Moreover, institutions are mandated to conduct fundamental rights impact assessments before deploying AI systems that could have a significant effect on the educational process (Mayer Brown, 2025). These assessments go beyond technical safety concerns and involve evaluations of potential risks to the right to education, equal access, non-discrimination, and academic freedom. The implementation of AI in education must be accompanied by documented evaluations demonstrating that such systems do not infringe upon the fundamental rights of learners and educators. In the context of IT curricula, these provisions acquire even greater importance. The integration of AI tools into the classroom must be strategically planned and pedagogically grounded, in order to avoid the marginalization of foundational knowledge and core competencies in computing.

Skills such as programming, algorithmic thinking, data structure design, and software architecture comprehension remain essential to developing critical expertise and ensuring the long-term employability and adaptability of students. Consequently, educational institutions must not treat AI systems as replacements for traditional instruction, but rather as enhancements-tools that support learning without undermining the integrity of the educational process (Digital Education Council, 2024).

Classification of AI Systems According to Risk

The EU AI Act establishes a four-tier risk classification system for artificial intelligence technologies, based on their potential impact on individual safety, fundamental rights, and societal values. The risk levels include: unacceptable risk, high risk, limited risk, and minimal risk. This classification plays a central role in determining the regulatory obligations applicable to different types of AI applications, including those deployed in educational settings (Artificial Intelligence Act, n.d.).

- Unacceptable Risk: This category includes AI systems that pose a clear and serious threat to individual safety or violate fundamental human rights. Such systems are strictly prohibited under EU law. Examples include AI used for mass surveillance, behavioral manipulation, social scoring, or targeting vulnerable groups without consent. In the context of education, this ban is essential to prevent the introduction of AI technologies that could result in coercive, discriminatory, or privacy-invasive learning environments.
- High Risk: This classification applies to AI systems that may significantly affect users' health, safety, or fundamental rights. Within the educational context, this includes tools used for automated student selection, knowledge assessment (e.g., AI grading systems), monitoring during examinations, and personalized learning pathways that could shape educational trajectories. These systems are subject to strict regulatory requirements, such as comprehensive documentation, mandatory human oversight, robust data governance practices, and prior conformity assessments to ensure compliance with EU standards before deployment (FeedbackFruits, 2024).
- Limited Risk: AI systems in this category do not pose substantial threats to individual rights but require a certain degree of transparency. For instance, AI-powered chatbots that provide administrative support or academic guidance fall into this group. Although relatively benign, it is still mandatory to inform users that they are interacting with an AI system.
- Minimal Risk: These systems carry negligible or no risk and are not subject to additional regulatory requirements. Common examples include AI-based spam filters, automatic translation tools, or content recommendation engines based on prior user interactions.

For AI systems classified as high-risk within education, the EU AI Act mandates a rigorous conformity assessment prior to implementation. This process entails identifying and analyzing potential threats to user rights, testing the system for accuracy and bias, and ensuring the presence of clear protocols for human oversight and real-time intervention when necessary. These measures are designed to guarantee that the integration of AI into education supports rather than undermines the foundational principles of transparency, accountability, and equity in learning.

Contractual Relationships in the Educational Sector in the Context of Artificial Intelligence Implementation

The digital transformation of education, propelled by the increasing integration of artificial intelligence (AI) technologies, is reshaping the legal relationships among educational institutions, students, and third parties. The deployment of AI tools in educational processes not only alters the modalities of knowledge dissemination and assessment but also raises critical issues concerning legal responsibility, transparency, and the protection of user rights. The incorporation of AI into educational settings necessitates a reevaluation of existing legal frameworks to address the complexities introduced by these technologies (Spalević and Ilić, 2024). Educational institutions must navigate the challenges of ensuring that AI applications comply with legal standards, particularly regarding data privacy, algorithmic fairness, and accountability. The dynamic nature of AI systems, which can evolve and learn over time, further complicates the assignment of liability and the enforcement of contractual obligations. Moreover, the global nature of AI technologies, often developed and maintained by international entities, introduces cross-jurisdictional

legal considerations. Educational institutions must be vigilant in understanding and adhering to both local and international legal requirements to mitigate potential legal risks associated with AI deployment.

Licensing Agreements and Obligations of Educational Institutions in AI Area

Educational institutions that implement AI systems frequently enter into licensing agreements with technology providers. These agreements delineate the terms of use for AI tools, specifying the rights and responsibilities of both parties, as well as measures for data protection and user privacy. According to guidelines from the SCL AI Group, such contracts should encompass clauses that ensure algorithmic transparency, provisions for human oversight, and clear procedures for addressing potential issues arising from AI application (SCL AI Group, 2023). Furthermore, licensing agreements must account for the dynamic capabilities of AI systems, including their ability to learn and adapt over time (Belović, Spalević and Jakšić, 2025). This necessitates the inclusion of provisions for regular updates, performance evaluations, and mechanisms for addressing unforeseen consequences of AI behavior. Institutions must also ensure that these agreements align with ethical standards and educational objectives, maintaining the integrity of the learning environment. The negotiation of licensing agreements requires a thorough understanding of both the technical aspects of AI systems and the legal implications of their use. Institutions should engage legal experts and technologists in the drafting process to create comprehensive agreements that safeguard the interests of all stakeholders.

User Consent and Informed Consent in AI systems

The utilization of AI tools in education often necessitates obtaining user consent, particularly when it involves the collection and processing of personal data. Consent must be informed, meaning that users are clearly apprised of how AI systems operate, the nature of the data collected, and the purposes for which the data will be used. This practice aligns with principles of contract law, where informed consent is fundamental to the validity of agreements (Linarelli, 2023). In educational contexts, obtaining informed consent is crucial for maintaining trust and ensuring compliance with data protection regulations. Institutions must provide transparent information about AI functionalities, data handling practices, and the potential implications of AI-driven decisions. This includes clarifying the extent to which AI influences assessments, learning pathways, and access to educational resources. Moreover, the process of obtaining consent should be ongoing, with opportunities for users to withdraw consent or opt out of specific AI applications. Institutions must establish protocols for managing consent preferences and ensuring that changes are respected and implemented promptly.

Internal Regulations and Digital Policies in AI Area

Educational institutions often establish internal regulations and digital policies governing the use of AI tools. While these documents may not constitute formal contracts, their acceptance by students and staff can confer contractual significance. For instance, policies may outline acceptable and unacceptable uses of AI tools, as well as the consequences of policy violations (Bishop and Stothart, 2025). The development of internal policies should involve a collaborative process, incorporating input from educators, students, legal experts, and technologists. Policies must be clearly communicated, accessible, and regularly updated to reflect technological advancements and evolving legal standards. Additionally, institutions should implement training programs to ensure that all stakeholders understand the policies and their implications. This proactive approach fosters a culture of compliance and ethical AI use within the educational environment.

Liability for Errors and Harm in AI Area

The application of AI tools in education can lead to errors, such as inaccurate evaluations or discriminatory decisions. In such instances, the issue of legal liability arises. Analysis by DLA Piper suggests that liability may be shared between the AI technology provider and the educational institution, depending on who had control over the implementation and use of the system (DLA Piper, 2021). Determining liability involves assessing the roles and responsibilities of each party, the foreseeability of the error, and the adequacy of safeguards in place. Institutions must ensure that their contracts with AI providers include clear terms regarding liability, indemnification, and dispute resolution mechanisms. Institutions should

establish internal procedures for monitoring AI performance, addressing grievances, and rectifying errors. This includes setting up oversight committees, conducting regular audits, and maintaining open channels of communication with stakeholders.

The Role of Contracts in Protecting User Rights in AI Area

Contracts play a pivotal role in protecting the rights of users of AI tools in education. Well-crafted agreements can provide mechanisms for appeals, access to information, and data protection. Recommendations from LexisNexis emphasize that contracts should include clauses that clearly define obligations related to privacy protection, data security, and dispute resolution processes (Bishop and Stothart, 2025). In addition to contractual provisions, institutions must implement practical measures to uphold user rights. This includes ensuring transparency in AI decision-making processes, providing explanations for AI-driven outcomes, and facilitating user participation in decision-making where appropriate. By integrating legal safeguards with ethical practices, educational institutions can create an environment where AI technologies enhance learning while respecting and protecting the rights of all participants.

Pedagogical Implications of AI Integration in IT Education

The integration of generative AI tools such as ChatGPT, GitHub Copilot, and similar platforms into higher education, particularly within the field of Information Technology (IT), has raised significant pedagogical concerns. While these tools provide students with personalized assistance, access to additional resources, and faster problem-solving capabilities, they also give rise to a fundamental dilemma: are students using these tools to deepen their understanding, or are they substituting independent thinking with automated outputs? Prather et al. observe that many students rely on generative AI as a first-line solution, even when they do not fully grasp the underlying material (Prather et al., 2023). In this context, AI is not employed as a learning facilitator but as a task executor-bypassing essential cognitive processes. This educational paradox results in students passing courses with the aid of AI tools without developing a deep understanding of core IT concepts, such as algorithmic complexity, memory management, or network architecture. The issue is further exacerbated by the fact that AI-generated solutions are often syntactically correct but semantically flawed. Lacking the requisite foundational knowledge, students are frequently unable to critically evaluate the quality of these outputs. Rather than cultivating analytical reasoning, students tend to perceive AI as an infallible source of knowledge, undermining the very objective of education: to develop autonomous problem-solvers capable of critically engaging with information. Educational institutions must therefore redefine the pedagogical use of AI-not as an automated assistant, but as a partner in reflective learning. One promising approach involves the introduction of assignments that require students to critically assess AI-generated content and articulate the rationale behind its use, thereby promoting metacognitive awareness and deeper conceptual engagement.

The Erosion of Foundational Skills: Programming and Algorithmic Thinking

One of the most pressing pedagogical challenges in the age of pervasive AI is the preservation of fundamental skills that constitute the backbone of IT education-namely, programming, algorithmic thinking, and systems comprehension. Increasingly, students in IT courses rely on AI to generate code, often bypassing the development of their own technical competencies. Zastudil et al. highlight that many students employ tools like Copilot to produce complete code solutions, often without understanding the logic that underpins them (Zastudil et al., 2023). This trend fosters superficial learning that is not transferable to complex, real-world problems. As a result, students may become proficient tool users without acquiring the deep expertise necessary for software innovation, maintenance, or debugging. This deficiency becomes particularly evident during internships or employment, where employers expect independent problem-solving and critical reasoning skills. Furthermore, the decline in algorithmic thinking represents not only a technical shortfall but also an epistemological one. Learning algorithms and data structures develops abstract reasoning and logical problem-solving skills, which are applicable beyond IT. When these skills are neglected during the educational process, students risk losing both their professional competitiveness and their broader cognitive capacity to engage with a world increasingly structured by digital logic. Thus, educators face a dual challenge: to encourage the use of AI for accelerating learning while simultaneously safeguarding the integrity of core technical knowledge. One strategy involves combining

AI-assisted tasks with traditional, manually coded assignments that require students to explain and reflect upon the AI-generated outputs.

Pedagogical Strategies for Preserving Fundamental Knowledge

In today's educational environment, where AI support is nearly ubiquitous, new pedagogical strategies are needed-not to exclude AI, but to incorporate it as a tool for deep learning. The key lies in reshaping the roles of instructors, curricula, and assessment mechanisms. An innovative model that addresses this challenge is the "Socratic Playground," developed by a research team led by Hu (Hu et al., 2025).

This AI-based environment adopts a Socratic method, where the system engages students in reflective dialogue, prompting them to follow a line of reasoning instead of immediately offering a solution. This strategy emphasizes the learning process rather than the end product. Another effective approach is the use of explanation-based pedagogy, where students are required to justify how they arrived at a solution, including how and why AI tools were employed. Instead of passively accepting the AI-generated content, students are encouraged to deconstruct, comment on, and adapt it.

This active engagement fosters deeper understanding and promotes the acquisition of transferable skills. A two-phase evaluation model can also be implemented. In the first phase, students complete assignments with the help of AI. In the second phase-without AI assistance-they must replicate, explain, or adapt their previous work. This model allows instructors to assess both conceptual understanding and independent thinking. Ultimately, the pedagogical integration of AI must prioritize self-reflective learning, in which students are not merely consumers of technological solutions but active participants in the construction of knowledge.

AI Literacy in IT Curricula

As regulatory frameworks such as the EU AI Act continue to evolve, the imperative to include AI literacy in IT curricula becomes more urgent. AI literacy in this context goes far beyond operational proficiency with AI tools-it entails a comprehensive understanding of how such systems function, their limitations, their data-processing mechanisms, and their broader ethical, legal, and societal implications. Mekić et al. emphasize that AI literacy must encompass not only technical training but also awareness of legal frameworks, ethical standards, and the social consequences of AI deployment (Mekić et al., 2024). Students in IT programs should develop fluency in key areas such as machine learning fundamentals, large language models (LLMs), algorithmic bias, and responsible AI development. To build sustainable and future-ready curricula, educational institutions must integrate technical knowledge with a humanistic perspective. Interdisciplinary courses combining computer science, law, ethics, and education can significantly enhance students' capacity to navigate the increasingly complex AI ecosystem with both competence and conscience (Spalević et al., 2024). AI literacy should become a mandatory graduation requirement, akin to programming fluency or database management skills. In today's IT education landscape, it is no longer sufficient to understand how to use AI tools; students must understand the systems behind them—and the implications of deploying those systems in real-world environments.

Recommendations for a Sustainable and Legally Aligned Development of Digital Education

The rapid digital transformation of education, accelerated by the integration of artificial intelligence (AI), demands that institutions navigate a delicate balance between innovation, legal compliance, and sustainability. While digital technologies offer unprecedented opportunities for personalized learning, increased access, and administrative efficiency, they also raise fundamental questions regarding data governance, legal accountability, and long-term educational quality. This chapter offers a comprehensive set of recommendations for the sustainable and legally aligned development of digital education. These recommendations draw on policy reports, international frameworks, and academic studies, with the aim of helping educational stakeholders ensure that digitalization supports-not undermines-the integrity, equity, and legal foundations of education.

Embedding Sustainability in Digital Education

One of the critical tasks in digital transformation is integrating the concept of sustainability-not only in ecological terms but also in pedagogical, technological, and institutional dimensions. García-Hernández

et al. emphasize that sustainable digital education must rest on open educational resources (OER), digital inclusion, responsible use of AI tools, and pedagogies that support long-term skill development (García-Hernández et al., 2023). Sustainable practices also imply minimizing reliance on proprietary technologies that lock institutions into long-term dependencies. Instead, educational institutions are encouraged to adopt open-source tools and promote digital literacy that enables students to become not just users but critical evaluators and co-creators of technology. Furthermore, sustainability involves recognizing the long-term risks of over-automating educational processes. AI systems should not replace human educators in fundamental pedagogical functions such as mentoring, assessment, and curriculum design. Rather, they should augment teaching in ways that preserve space for reflection, creativity, and theoretical grounding.

Legal Frameworks and Compliance: UNESCO's Common Digital Education Framework

As legal and ethical challenges grow in complexity, institutions require robust reference points for aligning their digital initiatives. In 2024, UNESCO launched a common framework to guide the digital transformation of education, identifying five interconnected domains: coordination and governance, infrastructure, digital skills and capacities, curriculum and content, and data governance (UNESCO, 2024). This framework stresses that legal compliance must not be an afterthought, but rather a foundational layer of digital education policy. For example, institutions must ensure that all AI systems used in grading, admissions, or content delivery adhere to principles of fairness, transparency, and informed consent. This is particularly critical in light of the EU AI Act, which categorizes education as a "high-risk" domain, imposing obligations such as risk assessments, documentation of decision-making processes, and human oversight mechanisms (Artificial Intelligence Act, n.d.). Compliance extends to international data protection standards, such as the GDPR (European Parliament and Council - Regulation (EU) 2016/679, 2016), which mandates lawful bases for data processing, user rights to access and correction, and limitations on automated profiling. Educational institutions must design their AI strategies to include privacy-by-design and ethics-by-default features from the earliest stages of system adoption.

The Digital Education Action Plan: Strategic Guidance from the EU

The European Commission's Digital Education Action Plan (2021–2027) serves as a key strategic document that defines the EU's vision for high-quality, inclusive, and accessible digital education. The Plan outlines two key priorities: (1) fostering a high-performing digital education ecosystem, and (2) enhancing digital skills and competencies for digital transformation (European Commission "Digital Education Action Plan (2021–2027)", 2020). For institutions, this implies a shift from sporadic technological adoption toward comprehensive and intentional strategies. One of the central recommendations is to institutionalize digital education-not through isolated experiments, but by integrating digital innovation into core policies, budgets, teacher training programs, and evaluation frameworks. The Action Plan also highlights the importance of ensuring equitable access to digital infrastructure and skills. Without addressing the digital divide, digital education risks reinforcing social inequalities rather than alleviating them. Therefore, sustainability is also a matter of social justice: systems must be designed to serve all learners, especially those from underrepresented or marginalized backgrounds.

Frameworks and Methodologies: OECD's Analytical Approach

To support evidence-based decision-making, the OECD has proposed a sophisticated analytical framework to help countries evaluate their digital education strategies (OECD "Policies for the Digital Transformation of School Education: Proposed analytical framework and methodology", 2023). The framework includes dimensions such as institutional governance, financial sustainability, technological interoperability, and impact measurement. This structured methodology allows policymakers and educators to move beyond anecdotal evaluations and instead design interventions grounded in measurable goals. For example, the use of AI tools in classrooms can be assessed not only in terms of efficiency but also with respect to their effects on learning outcomes, privacy risks, and student agency. A notable recommendation from the OECD is the creation of inter-sectoral task forces, where educators, legal experts, technologists, and students collaborate to evaluate and guide the digital transformation process. Such collaboration ensures that decisions are not siloed in IT departments, but reflect educational, ethical, and legal values.

Sustainable Data Governance in Education

As the use of data-intensive AI systems increases, sustainable data governance becomes a foundational requirement. Lee outlines seven principles for developing sustainable data practices in education: (1) data stewardship, (2) data quality, (3) ethical use, (4) transparency, (5) environmental impact, (6) supportive policy, and (7) continuous improvement (Lee, 2025). Implementing these principles requires more than technical fixes. Institutions must build cultures of accountability where data collection is justified, minimized, and explained to all stakeholders. For example, when AI systems are used to monitor student behavior or performance, transparency about what is being tracked-and why-is essential. Educational institutions should also conduct environmental audits of their digital infrastructure. AI systems, particularly those based on large models, consume significant computational resources. Incorporating "green AI" principles, such as efficiency optimization and server sustainability, is necessary for aligning with broader ecological goals. Institutions must publish data ethics charters that define internal standards for data use, sharing, and storage. These charters help ensure alignment with both legal norms (e.g., GDPR) and institutional values such as academic freedom, fairness, and student autonomy.

Integrating Sustainability into Computing and IT Education

Sustainability should not only guide how we use digital systems, but also how we teach about them. Moreira et al. propose a roadmap for integrating sustainability into computing education, which includes key domains such as systems thinking, environmental and social impact, ethical reflection, and legal literacy (Moreira et al., 2024). Their approach is based on the premise that future IT professionals must not only understand algorithms and systems design but also be capable of assessing how their creations affect society and the planet. This can be achieved through course modules on sustainable design patterns, low-impact coding, algorithmic accountability, and legal constraints in software development. Moreover, the roadmap suggests that sustainability be treated as a transversal competency across all courses-not isolated in elective modules. This ensures that every computing student, regardless of specialization, is equipped to navigate the increasingly complex terrain of responsible digital innovation. Such curricular transformations require collaboration between academic departments, policy bodies, and professional associations. Accreditation agencies should also update their criteria to include sustainability and legal compliance as core competencies for computing degrees.

Policy Recommendations and Institutional Responsibilities

In light of the discussions above, this section outlines concrete policy and institutional recommendations for achieving a sustainable and legally aligned digital education ecosystem:

1. Adopt and adapt UNESCO's digital transformation framework to local legal and pedagogical contexts, ensuring cross-sectoral coordination and ethical governance.
2. Integrate AI ethics and legal compliance training into teacher education programs, IT staff training, and student orientation curricula.
3. Develop internal regulatory instruments, such as AI usage policies, algorithmic transparency reports, and data ethics charters.
4. Establish ethics and compliance committees tasked with conducting impact assessments and reviewing all new AI integrations.
5. Mandate open data practices and open educational resources (OER) to reduce dependency on proprietary platforms and ensure long-term knowledge accessibility.
6. Introduce interdisciplinary courses on sustainability in computing, co-taught by faculty from IT, law, education, and environmental sciences.
7. Perform regular audits of AI system performance, bias, environmental impact, and legal compliance, publishing transparent reports for stakeholders.
8. Incentivize open-source development and responsible innovation through grants, awards, and institutional partnerships.

Conclusions

The integration of artificial intelligence into education represents a paradigmatic shift in both pedagogical practice and legal accountability. As this paper has demonstrated, the European Union's AI Act offers more than a regulatory checklist-it introduces a framework that fundamentally redefines institutional responsibilities, user rights, and the structure of educational relationships in the digital era.

One of the core findings of this paper is that the widespread use of AI tools in IT education poses both pedagogical and legal challenges. From a pedagogical standpoint, students are increasingly relying on AI to solve problems, write code, and complete assignments, often without understanding the underlying principles. This trend threatens the development of critical foundational skills in programming, algorithmic thinking, and system design. Without these competencies, students risk becoming mere operators of AI rather than creators or critics of it. Moreover, this development risks undermining the very goals of IT education: intellectual autonomy, technical mastery, and the capacity to innovate responsibly.

From a legal perspective, the EU AI Act classifies education as a high-risk domain. This classification carries significant implications: institutions must now ensure transparency, conduct risk assessments, and implement mechanisms for human oversight. The deployment of AI in educational settings is no longer a neutral technological choice but a legally binding action that generates contractual obligations. Whether through licensing agreements, consent forms, or internal digital policies, institutions must respect principles of informed consent, fairness, and accountability. Failure to do so could result in civil liability-not only regulatory non-compliance.

Furthermore, the paper has shown that sustainability must be a guiding principle in digital education. Sustainability here refers not only to environmental responsibility, but to pedagogical and institutional resilience. As emphasized in the final chapter, integrating sustainability into computing education involves embedding ethical reflection, legal awareness, and systems thinking into curricula. This is essential to developing future IT professionals who are not only technically capable but also socially and legally literate. To ensure a sustainable and legally compliant future for digital education, several actionable recommendations have been outlined. These include adopting UNESCO's framework for digital transformation, implementing EU and GDPR-aligned policies, developing interdisciplinary courses on AI ethics and law, and conducting regular audits of AI systems. Institutions are also encouraged to reduce dependency on proprietary platforms by investing in open-source and transparent AI tools.

EU AI Act presents both a challenge and an opportunity. It challenges institutions to rethink their use of AI-not merely in terms of efficiency, but in terms of ethics, legality, and long-term educational goals. At the same time, it offers an opportunity to realign digital education with the foundational values of higher education: knowledge, critical inquiry, equity, and integrity. Only by integrating AI in a balanced, thoughtful, and law-conscious manner can education remain both innovative and principled in the era of intelligent machines.

Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, R.I., M.P. and M.S.; methodology, R.I., D.V, N.J. and M.J.; formal analysis, R.I. and D.A.; writing—original draft preparation, R.I., D. A. and N. J.; writing—review and editing, R.I., M.J., D.A., and M.S. All authors have read and agreed to the published version of the manuscript.

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In a recent study of reaction times (Busk, 2014) ... (ibid, str.105).

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In 2012 Stosic compared reaction times ... (ibid, page 102).

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As has been shown (Busk & Serlin, 1993) ...

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Second time: Yan, G.et al. (2006) found ... (ibid, p. 12)

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These result present (‘’ Study Finds, ‘’ 2002) ...

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The first definition of intrinsic motivation gave Decy (1975; see Suzić 2005, p. 108) ...

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(James, 1890/1983)

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(Myers, 2000, ¶ 5)

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Employee Benefit Research Institute. (1992, February). Sources of health insurance and characteristics of the uninsured (Issue Brief No. 123). Washington, DC: Author.

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8th GVU's WWW User Survey. (Od). Retrieved August 8, 2000, from http://www.cc.gatech.edu/gvu/user_surveys/survey-1997-10/

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Miller, M. E. (1993). The Interactive Tester (Version 4.0) [Computer software]. Weastminster, CA: Psytek Sesvice.

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Thank you Reviewers!

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